DOCUMENT RESUME

ED 367 297 IR 016 557

AUTHOR Moursund, David
TITLE Problem-Solving Models for Computer Literacy: Getting Smarter at Solving Problems. Student Lessons.
INSTITUTION International Society for Technology in Education, Eugene, OR.
REPORT NO ISBN-1-56484-020-4
PUB DATE 93
NOTE 177p.; For teacher lesson plans, see IR 016 543.
AVAILABLE FROM International Society for Technology in Education, 1787 Agate St., Eugene, OR 97403-1923.
PUB TYPE Guides - Classroom Use - Instructional Materials (For Learner) (051)

EDRS PRICE MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS *Computer Assisted Instruction; *Discovery Learning; Experiential Learning; Glossaries; Instructional Materials; Interdisciplinary Approach; Journal Writing; Learning Activities; Metacognition; Modeling (Psychology); *Problem Solving; Secondary Education; Teaching Methods; Transfer of Training

ABSTRACT

This book is intended for use as a student guide. It is about human problem solving and provides information on how the mind works, placing a major emphasis on the role of computers as an aid in problem solving. The book is written with the underlying philosophy of discovery-based learning based on two premises: first, through the appropriate study of the discipline of problem solving, a student can get better at solving both school problems and nonschool problems; second, computers are a powerful aid to problem solving, and a student can get better at solving certain types of problems by learning to make appropriate use of computers. Methodologies that cut across all disciplines--such as journals, learning to learn, metacognition, and modeling--are discussed. The chapters are as follows: (1) Introduction; (2) You Are a Smart Person; (3) What Is a Problem?; (4) A Four-Step Plan for Solving a Problem; (5) Problem-Solving Strategies; (6) Getting Better at Thinking; (7) Transfer of Learning; (8) Modeling; (9) General Purpose Computer Tools; and (10) Computer Systems. A glossary is included. (TMK)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

About the Author

David Moursund has been teaching and writing in the field of computers in education since 1963. He is a professor at the University of Oregon in the College of Education. Some of Dr. Moursund's major accomplishments include:

- Author or coauthor of about 25 books and numerous articles.
- Chairman of the Department of Computer Science, University of Oregon, 1969-1975.
- Chairman of the Association for Computing Machinery's Elementary and Secondary School Subcommittee, 1978-1982.
- Founder, International Council for Computers in Education (ICCE), 1979. The name of this organization was changed to the International Society for Technology in Education (ISTE) in 1989 when it merged with the International Association for Computing in Education.
- Chief Executive Officer, ICCE, 1979-1989.
- Executive Officer, ISTE, 1989-present.

Book Cover
Tamara Kidd
Book Design and Production
David Moursund
Editing and Production Assistance
The Electronic Page

© International Society for Technology in Education, 1993
1787 Agate Street, Eugene, Oregon 97403-1923
Order Desk: 800/336-5191
Phone: 503/346-4414
Fax: 503/346-5890
CompuServe: 70014,2117
Internet: ISTE@Oregon.uoregon.edu

ISBN 1-56484-020-4

BEST COPY AVAILABLE

Problem-Solving Models for Computer Literacy

Getting Smarter at Solving Problems

Student Lessons

by

David Moursund

© International Society for Technology in Education, 1993

Table of Contents

Preface for Teachers i

Preface for Students vii

Chapter 1. Introduction 1

Chapter 2. You Are a Smart Person 17

Chapter 3. What Is a Problem? 27

Chapter 4. A Four-Step Plan for Solving a Problem 43

Chapter 5. Problem-Solving Strategies 57

Chapter 6. Getting Better at Thinking 71

Chapter 7. Transfer of Learning 87

Chapter 8. Modeling 103

Chapter 9. General Purpose Computer Tools 119

Chapter 10. Computer Systems 135

Glossary 153

Preface for Teachers

Specific Intended Audience

Problem-Solving Models for Computer Literacy is specifically designed to be used as a supplemental text in a secondary school computer literacy course. When used in that format, the book contains sufficient materials to be used two days a week or part of each day in a half-year course.

However, *Problem-Solving Models for Computer Literacy* can also be used in a wide variety of other settings. It can be used in a "Modern Problems" class in the social studies; it can be used in a course on problem solving; it can be used in a math course. In all cases the emphasis is on problem solving in general and on the role of computers as an aid to problem solving.

This book is based on the following two premises. The premises are strongly supported by the research literature.

1. Through the appropriate study of the discipline of problem solving, a student can get better at solving both school problems and nonschool problems.

2. Computers are a powerful aid to problem solving. A student can get better at solving certain types of problems by learning to make appropriate use of computers as an aid to solving the problems.

Computer Literacy Courses

There are many different versions of computer literacy courses. A typical computer literacy course may focus on just one of the following themes, or it may draw from several of them:

A. Generic tool approaches that focus on use of one or more of the general purpose tools, such as database, graphics, spreadsheet, telecommunications, and word processor. These tools are interdisciplinary, useful at all levels of education, and useful both in school and outside of school.

   An alternative is to build a computer literacy course around applications software that fits the needs of people in a specific applications area. Music software provides a good example, as does software for use in the fine arts. A computer literacy course could be

built around a specific piece of desktop publishing software or a specific piece of hypermedia software.

B. Computer programming, making use of languages such as BASIC and Logo.

C. A reading, talking, and critical analysis approach. Here the emphasis is on understanding and analyzing the history and current applications of computers and how computers are affecting our society.

There are many definitions of computer literacy. Generally speaking, computer literacy is a blend of computer science (including computer programming), computer applications, and computers in society (including reading, writing, and talking about computers and their impact on our society). However, there should be one unifying theme: **computers are a new and powerful aid to problem solving; they extend the capability of the human mind.** Computers can be used to help solve problems in every area of human intellectual endeavor. The capabilities of computers are having a major impact on our world.

Problem-Solving Models for Computer Literacy is designed to provide a unifying and underlying theme of problem solving in a computer literacy course. There is a lengthy set of Teacher Lesson Plans that accompanies this book. It contains detailed lesson plans and specific suggestions on how to integrate problem solving into each of the general types of computer literacy courses listed above.

Guided Discovery-Based Learning

Problem-Solving Models for Computer Literacy contains an underlying philosophy of discovery-based learning. One reason for this is the general nature of the computer field. The computer field is changing very rapidly. The computers your students will have available in their homes and on their jobs 20 years from now will be a hundred or a thousand times as powerful as the computers they now have available in school. This means that there must be a strong focus on learning to learn and on transfer of learning. A guided discovery-based learning environment contributes greatly to learning to learn, and it facilitates transfer of learning.

Puzzle Problems

Many books on problem solving are full of "puzzle problems." Here is an example.

```
  TWO
+ TWO
 FOUR
```

In this puzzle, each letter stands for one of the digits 0, 1, 2, ..., 9. The letter F stands for a digit that is larger than 0. The goal is to find one or more solutions. (Typically, a puzzle problem always has at least one solution. Of course, in the real world there are lots of problems that have no solution.)

For many students, puzzle problems are challenging and fun. Unfortunately, there are two distinct drawbacks to making extensive use of them in instruction.

1. The research suggests that there is relatively little transfer of learning from puzzle problems to other problem-solving tasks. That is, practice in solving puzzle problems helps a student to get better at solving the specific types of puzzle problems being studied. It does not help students to get better at solving real-world problems or the other types of problems they encounter in school.

2. Many students are turned off by puzzle problems.

Problem-Solving Models for Computer Literacy is quite different from the puzzle-problem books. It focuses on the underlying theory and practice of the discipline of problem solving. It focuses on methodologies such as journaling, learning to learn, metacognition, and modeling that cut across all disciplines. It lays foundations that will serve students throughout their lives.

Problem-Solving Software

There are two major categories of problem-solving software that are not discussed in this book. The first type is software specifically designed to help teach problem solving. A number of the educational software publishers make available a wide range of such software. The second type is software specifically designed to help solve certain types of problems, such as math problems. This type of software is of growing importance in each academic discipline. The inclusion of either or both types of software in a

course on computers and problem solving is quite appropriate. However, this book can be used independently of any specific piece of software or hardware.

Computer and Noncomputer Aids to Problem Solving

The computer is but one of many different powerful aids to problem solving. Reading, writing, arithmetic, speaking, and listening are certainly powerful aids to problem solving.

Most students in your class will have had little or no formal instruction in problem solving. Thus, you will be faced by two interrelated tasks:

1. To help your students learn about the general discipline of problem solving. This instruction is oriented toward helping your students get better at dealing with all sorts of problems and using all sorts of aids to problem solving.

2. To help your students learn the capabilities and limitations of computers as an aid to problem solving.

It should be clear that the first task is more general. It does relatively little good to teach the specifics of problem solving in a computer environment if students have no knowledge of general ideas of problem solving. However, it does make sense to use a computer environment as a motivation to study problem solving in general, and then to focus specifically on how computers affect this discipline. That is the design philosophy of this book.

The Student Lessons in *Problem-Solving Models for Computer Literacy* contain only a modest amount of specific focus on computers. However, each topic has been carefully selected to fill a dual role. First, it has been selected because it is foundational within the discipline of problem solving in general. Second, it has been selected because it easily ties in with studying the roles of computers in problem solving.

To a great extent the Teacher Lesson Plans rather than the Student Lessons provide the bridge between these two areas. This is because the student text is designed to be used in a wide variety of instructional settings. Thus, it is important that you, the course instructor, focus on bridging between problem solving in general and problem solving within the context of the specific course that you are teaching. The Teacher Lesson Plans

provide a number of quite specific suggestions on how to do this in a variety of instructional situations.

Don't Expect Miracles

Every student in your class is a smart, problem-solving person. Your students have been developing their problem-solving skills throughout their lives. Your course, and the specific instruction on problem solving based on this book, will be a very modest-sized intervention in the lives of your students. It can make a significant contribution. However, it is a small intervention relative to the total amount of time each student has already spent on learning to solve problems. Getting smarter at solving problems is a life-long task.

Preface for Students

ORGANIZE YOUR THINKING

There is a box like this at the beginning of each chapter. It contains some of the highlights of the chapter. Spend a minute or two reading and thinking about these highlights. Research says that this will be time well spent. It will help you to learn the chapter material much better.

The Preface is about:

- Aids to the human mind.
- Thinking about how you learn.
- Using computers to help you solve problems.

The Computer Is an Aid to the Human Mind

This is a book about how computers can help you to solve problems. However, a computer is merely a tool to help your mind. Your mind still has to do most of the thinking!

Thus, this book provides a lot of information about how your mind works. It explains how to help your mind get better at solving problems. If you practice the ideas in this book, you will get a lot better at solving problems in school and outside of school.

Other Aids to the Human Mind

There are many aids to the human mind. Reading, writing, and arithmetic are all very important mind aids. They help you to solve problems that you could not solve just by using your mind all by itself.

Reading is especially important. If you can read this book, you can read well enough so that you can learn new things by reading. Being able to read opens up a whole new world. It allows you to solve problems by reading about how others have solved the problems.

Another important mind aid is learning to learn. There are lots of ways to learn new things. As you know, different people learn in different ways. Some people learn best by "seeing"—by receiving information through their eyes. Others learn best by "hearing"—by receiving information through their ears. Still others learn best by "physically doing"—by being physically engaged in carrying out the processes to be learned.

These differences in how people learn make it difficult for a teacher to teach only in the way that seems best for you. This means that it is important for you to learn how you best learn. You must become responsible for your own learning.

Also, the way you learn best may vary with different things that you want to learn. Think about sports and how you get better at sports. Think about how you learned to make friends and how you get better at making friends. Think about how you learned how to read and how you get better at reading. Think about math classes and how you get better at solving math problems.

Now be aware of what you just did. You were thinking about how you learn. You are a unique person. You are different from every other person. You are the only person who can really know yourself. You are the only person who can really learn how you learn best.

One of the most important learning things that you can learn is how to learn. How does your mind work as it learns new things? What helps it to learn rapidly and well? What helps it to remember important new ideas? What helps it to get better at solving problems?

You learn many new things every day. This means that you get a lot of practice in learning. Some of this learning occurs without much effort on your part. For example, you see and hear a television ad, and you learn a little about the product being advertised. You hear a friend using a new word, and you automatically start using that new word.

But other learning takes more effort. Over the centuries, humans have accumulated a great deal of knowledge and wisdom. Many brilliant thinkers, such as Marie Curie and Albert Einstein, have contributed to our knowledge. There is lots to learn, and more new knowledge is being developed each year.

One reason we have schools is to make it easier for people to learn. One goal of this book is to help you get better at learning. There is a simple way to get better at learning. As you learn, think about learning. Examine your

own personal learning processes. Figure out what works best for you. Experiment. Try different approaches. Gradually you will get better at learning.

You Will Need a Journal

Early explorers kept journals or diaries in which they wrote about their travels. As you read this book, think of yourself as an explorer. You are exploring the content of this book. You are exploring your mind and how it reacts to the book. You are exploring computers and how they can help you solve problems.

Many of the activities in this book ask you to write in a journal. You will need a bound book, such as a spiral-bound notebook, to use as a journal. Please get yourself a journal before starting to read the first chapter of this book. Keep it with this book so that you will have it when you need it.

Educational researchers have thought a lot about how to help students learn better. They have decided that writing in a journal helps most students learn better. This seems to be true in every school subject. And it works well for both young people and adults. Don't be surprised if you see your teacher doing journaling!

What This Book Is About

This is a book about human problem solving. It places a major emphasis on the roles of computers as an aid in problem solving. Computers are a very powerful aid. Computers are especially useful in solving the types of problems that you study in school. You can get much better at solving many types of problems by learning to use computers as an aid to problem solving.

This book will help you get better at problem solving. However, don't expect miracles. It has taken your entire life to get as good at problem solving as you are now. This book will help you get better. But getting better at problem solving takes time and effort.

PREFACE SUMMARY

There is a box like this at the end of each chapter. It contains a summary of a few of the key ideas in the chapter.

The purpose of the Preface is to get you started in thinking about what this book is about. Some key ideas include:

1. A computer is a powerful aid to the human mind. Reading, writing, and arithmetic are also powerful mind aids.

2. It is important for you to learn how you best learn.

3. By studying and practicing, you can get better at problem solving.

Chapter 1
Introduction

ORGANIZE YOUR THINKING

You live in a complex and rapidly changing world. One purpose of schools is to help you learn to cope with the types of problems you will encounter when you become an adult. This means that you need to:

- Learn how to learn.
- Get better at solving problems.

There are many ways to get better at problem solving. One way is to write ideas in your journal that occur to you as you read.

Some Aids to Learning

If you skipped over the Preface for Students, please go back and read it. It tells you what this book is about. It lists several of the key ideas. It is important that you think about these ideas before reading the rest of the book. This will help you to learn more and better from this book.

Also, did you think about the ideas in ORGANIZE YOUR THINKING? This brief introduction to the chapter is called an **advance organizer**. Its purpose is to get your mind to start thinking about the key ideas in the chapter. Research says that use of an advance organizer will likely help you to learn better. Many teachers and books make use of advance organizers.

This book contains a Glossary. When an important new term, such as "advance organizer," is first discussed, it appears in **boldface** type. The Glossary contains definitions of these terms. It is very important that you practice using these new terms. Use them in your talking and in your writing. Make them part of your working vocabulary. This will help you to learn the important ideas in this book.

Writing in Your Journal

This book is designed to help you learn some very important ideas. Probably you have heard the expression:

You can lead a horse to water, but you can't make it drink.

What do you think this expression means? How does it relate to reading and using this book?

Before going further in this book, get your journal started. Write your name in the journal. Number the first 20 pages or so. Use both sides of the pages in order to save paper. Write the current date on the first page.

Each day you use this book, draw a line across the page below the previous writing in your journal. Skip a few lines and write the date. Remember to make use of the both sides of the pages.

✍✍ Note: The hand-and-pencil symbols are a suggestion that you *may* want to write an answer in your journal. In some places in the book we will make a *very strong suggestion* that you write in your journal. Then we will give you a suggested title line for your journal entry.

Begin ✍✍ (You may want to write in your journal.)

Did you think about answers to the questions about the horse and water? Did you think of more than one possible answer for each question? If not, please read the questions again. Think about several answers to each question. You may want to write them in your journal. You may want to draw a picture of a horse and water in your journal. Pictures are one form of writing.

End ✍✍

You can learn a lot from this book. But to learn from this book, you will need to think about what you are reading. You will need to practice the ideas. It will help you a lot if you write down some of your thoughts.

Writing and talking are closely related to thinking. To write or talk clearly, you must be able to think clearly. Practice in writing and talking clearly will help you get better at thinking clearly.

As you read, make notes about the ideas that seem most important to you. If a picture forms in you head, draw the picture in your journal. When the book asks you a question, jot down an answer in your journal. If you think of a question you would like to ask your teacher, write it down. Maybe you will think of a question that you want to think about some more. Write it down so that you can come back to it when you have more time.

The World Is Changing

The world you live in is a lot different from the world your grandparents lived in when they were young. When your grandparents were young, they did not have color television (no MTV!), jet planes, or vaccines to prevent polio. They did not have fast-food restaurants, cassette tape recorders, and VCRs. They did not have communication satellites, fiber optics, and cellular telephones. They did not have computers and video games.

You live in a rapidly changing world. It is called the **Information Age** because so many people have jobs working with information. (Remember, you can find a definition of Information Age in the Glossary. Read that definition now. It contains some ideas not given in this chapter.)

Your teacher is a person who works with information. All people who use computers work with information. A computer is an information-processing machine. It can deal with information that can be represented using words, pictures, and sounds.

Of course, not all people have jobs working with information. Many people work with machines used to manufacture cars, refrigerators, television sets, and so on. At one time more than half of all workers in the United States had such jobs. That was called the Industrial Age. But now less than one-fifth of the jobs in the United States are of that sort. This number is still decreasing.

Many people have service jobs. They work as clerks in a store, tellers in a bank, nurses, truck drivers, and so on. They need to be good at working with other people. Often they make use of electronic machines, such as a cash register or a computer, to help them do their work. The number of people doing this type of job is increasing rapidly.

By the time you get to be an adult, there will already be many changes from the way things are now. There will be new types of music. There will be new forms of entertainment (3D video games and 3D television). There will be new medicines, new foods, new forms of clothing. There will be many kinds of jobs that do not yet exist. Computers will help do many different jobs.

Teachers know that you (and they) live in a rapidly changing world. They want to help you learn to deal with change. Schools are designed to help prepare you for the future.

Begin ✍✍ (You may want to write in your journal.)

Think about some changes in the world during the past few years. Make a list of some of these changes. Put a check mark beside each of these that strongly affects you.

End ✍✍

Learning to Think

Schools have many goals. Two of them are:

1. To help students learn some basic information and develop some basic skills.

2. To help students learn to think and solve problems using basic information and skills.

This may seem simple. First, you need to learn some basic information and you need to gain some basic skills. But perhaps these thoughts are going through your head:

> I wonder what information is important enough to learn? For example, is it important to memorize the name of each state, where it is located on the map, and each capital city? What if I forget some of what I am supposed to have memorized? Is it all right to look up stuff in a book instead of memorizing it?

What skills are really important? I understand the need for reading, writing, and arithmetic. Is having neat handwriting an important skill? Is being able to play a piano or sing on key an important skill? Is knowing how to touch-type fast and accurately an important skill?

Second, you need to learn to think and to solve problems using basic information and your skills.

What does "to think" mean? How can I tell if I am good at thinking? Is it possible to get better at thinking? How are thinking and problem solving related? Can computers think?

As you can see, these two goals are not so simple. Let's give some examples. First, let's consider an example having to do with spelling and writing. Spelling requires memorization. You must memorize the correct spelling of specific words and you must know certain rules to help you spell words. Writing involves thinking. You must learn to organize and express your thoughts.

Begin ✍✍ (You may want to write in your journal.)

Now, what is the best way to get better at writing? Should you spend your time memorizing the correct spelling of more and more words? Or should you spend your time learning to organize and express your thoughts? Which is better for you? Do you think that the answer is the same for every student?

Probably you have used a word processor on a computer. Most word processors have a spelling checker that can help find misspelled words. Suppose that whenever you needed to write, you could use a word processor with a spelling checker. Do you think this might change how much time you spend memorizing the correct spelling of words?

End ✍✍

For a second example, we will look at math. In your math classes you have memorized a large number of math facts. Probably you have memorized number facts, such as the times table:

x	1	2	3	4	5	Etc.
1	1	2	3	4	5	
2	2	4	6	8	10	
3	3	6	9	12	15	
4	4	8	12	16	20	
5	5	10	15	20	25	
Etc.						

You have memorized how to add up a column of numbers, how to do subtraction, how to multiply numbers, and how to divide numbers. You have spent many hours practicing these skills.

Begin ✍✍ (You may want to write in your journal.)

But a hand-held calculator can help do addition, subtraction, multiplication, and division. Think about that for a minute. It took you a long time to learn how to do pencil-and-paper long division. It takes only a few minutes to learn how to use a calculator to do long division. Calculators are cheap and readily available. Why should you use your school time and brain power learning to do long division by hand?

End ✍✍

This is not an easy question. There are other questions like it that are even harder. A computer can solve many different kinds of problems. A computer can solve many of the types of problems that you study in school. Suppose a computer can solve a type of problem that you are studying in school. What should you learn about solving that type of problem?

As you think about this question, you should be aware that new and better computers are being developed. That is, computers are getting more and more capable. Should you spend time in school this year learning to do something that next year's computers will likely be able to do?

These questions are very important. Please spend some time writing about them in your journal.

Begin ✍✍ (Please write in your journal.)

Make a title for this journal entry. Your title might look like this:

_____

LEARNING ABOUT PROBLEMS THAT COMPUTERS CAN SOLVE

Note: You will want to label your journal entries in a clear fashion. One way to do this is to begin each entry with a title line. When we strongly recommend that you write in your journal, we will suggest a title line for you. But it is all right to make up your own title lines.

You may also note that this question has no right answer. You are to give your own opinion. You should give arguments to support your opinion.

End ✍✍

Problem Solving

Educators know that the best way to prepare you for the future is to help you get better at learning, thinking, and problem solving.

Once you get good at learning, you can learn the new things that the future will bring.

Once you get good at thinking, you will be able to think clearly about the new things that the future will bring. Chapter 6 contains many ideas on how to get better at thinking. You may want to look at it right now. Remember, you are in charge of your own learning. There is no rule that says a book must be read from front to back!

Once you get good at solving problems, you will be able to solve the new problems that the future will bring. There are many ways to get better at solving problems. One way is to learn the **basic skills**:

1. Learn to speak and listen.

2. Learn to read and write.

3. Learn to make use of arithmetic and mathematics.

You know that schools spend a lot of time on these basic skills. Every educator knows that these are important.

People have developed a number of other aids to problem solving. This book spends a lot of time talking about two types of aids—strategies and tools.

1. **Strategies—plans of attack**. A **strategy** is a general way to try to solve problems. It is easy to learn some strategies that will help you to solve many different problems. A few are listed below. Many more will be discussed later in this book.

   A. Break big problems into smaller problems. (The smaller problems may be much easier to solve.)

   B. Draw a picture or a diagram to help you see what is happening in the problem. (The human mind is very good at dealing with pictures.)

   C. Use brainstorming, either by yourself or in a group. (This is a good way to get some ideas about a hard problem.)

   D. Make use of reference books. (A good way to solve a problem is to look up how to do it in a book.)

   E. Learn to use a computer. (A computer can solve or help solve many different kinds of problems.)

2. **Tools that help solve problems**. People have developed a wide variety of tools to help them solve problems. Several examples are given in the next two paragraphs.

Throughout recorded history, people have been developing tools to help them solve problems. First they developed tools to extend the capabilities of the human body. Examples include the club, spear, knife, hammer, plow, microscope, and telescope.

Then they developed tools to help in communication and transportation. Communication aids include the telegraph, telephone, and two-way radio. Transportation aids include the bicycle, train, car, and airplane.

More recently, people have developed the computer. The computer is a general purpose tool designed to extend the capabilities of the human mind. It is useful in every subject that you study in school. It is an everyday tool in many jobs that adults do. Thus, it is very important that you learn how to use a computer as an aid to problem solving.

Begin ✍✍ (You may want to write in your journal.)

Think about tools that you use. You use lots of different tools. A comb and a toothbrush are tools. Make a list of tools that you often use. For each tool, identify the problem it helps you to solve.

End ✍✍

Goals of This Book

This book has two specific goals:

1. To help you get better at solving problems.

2. To help you learn some of the roles of computers as an aid to solving problems.

These are big goals, and this is a relatively little book. As you read this book you will learn some basic ideas. But you will need to practice these ideas if they are going to make any difference in your life. You will need to practice whenever you run into a problem. This means you will need to practice when dealing with your friends and other people, when you are at home, and when you are at school.

Different Levels of Thinking Skills

There is quite a difference between learning some basic facts and learning to think using the facts. See how well you can do on the following four-question quiz.

A1. Columbus discovered America in the year ____.

A2. The Earth orbits about a star we call the ____.

A3. The name of the first president of the United States is ____.

A4. The name of the state located just to the north of Oregon is ____.

Each of these questions asks you to provide a fact—a piece of information—for an answer. It is relatively easy to teach facts and to test whether students have memorized the facts being taught.

Now consider the following questions:

B1. Columbus discovered America in the year 1492. What was he trying to accomplish on his historic voyage, and why was it important to try to accomplish it?

B2. The Earth orbits about a star we call the sun. How do we know this? (You might want to describe several different scientific experiments that could be used to prove the assertion.)

B3. The name of the first president of the United States is George Washington. What was the process that led to his becoming president, and why didn't he become the king of the United States?

B4. The name of the state located just to the north of Oregon is Washington. Give some reasons why this geographic region of the United States is divided into exactly two states. (Why not just one, or why not more than two? Remember, the original Oregon Territory was much larger than the current state of Oregon.)

Notice the big difference between the first group of questions and the second group of questions. The first four questions all ask for facts. To answer the questions, one must have memorized the facts. The questions do not test for relationships among these facts and related facts. The questions do not test for understanding of the meaning or use of the facts. These are examples of **lower-order thinking skill** questions.

The typical human brain is able to memorize and rapidly recall many thousands of facts. Some people are much better at this than others. Some of the very best memorizers get to be on television quiz shows. Viewers are impressed by their powerful ability at immediate recall of isolated facts.

Of course, some people are not very good at memorizing facts. In any case, it takes a lot of time to memorize a large number of facts. Also, the

brain has a natural tendency to gradually forget memorized facts that it does not use frequently.

Our school systems long ago decided that it is far better to take time away from memorizing and use it to teach reading. With reading skills, one can make use of books to look up facts. Similarly, many schools are now teaching students to make use of computers to store and look up facts.

The second group of questions relates to the first group. Answering them requires making use of a variety of facts. But they can be answered by drawing upon quite a wide range of facts. Failure to recall some specific fact is not likely to stand in the way of providing a good answer to a question. Answering these questions tends to require understanding of principles underlying the facts and relationships among facts. These questions test **higher-order thinking skills**.

There is one subtle but important point. If one is given the questions in advance, then questions B1-B4 become merely somewhat more complex examples of lower-order skill questions. A student can look up or ask a friend the needed facts, the underlying principles, and relationships among the facts. An answer can then be memorized for later regurgitation.

The same general statement holds for problem solving. A person has a problem when a situation is encountered in which the person is unable to immediately achieve a desired goal. If the same problem situation occurs over and over again, it may well be appropriate to memorize how to achieve the desired goal and to practice the necessary steps so that they represent no obstacle. Then the problem is no longer a problem, since there is no barrier to immediately achieving the desired goal.

Education for problem solving would be simple if the typical person only encountered a small number of problems while functioning in our society. The person could study each type of problem in advance, memorize the steps needed to solve each type, and practice them to a satisfactory level. Unfortunately, the number and variety of problems a person is apt to encounter is essentially unlimited. It is not possible to function effectively based purely on memorized solutions to frequently occurring problems. A good memory is useful. But even more useful is good skill at dealing with new and unfamiliar situations. That is what problem solving is all about.

Learning From the Activities at the End of the Chapter

A few people can learn new ideas just by reading a book. But most people need to practice the ideas if they are going to learn them. That is why teachers give assignments.

There are a number of activities at the end of each chapter. Some just ask you to do some thinking. Others ask you to talk to some of your friends and other people. Still others ask you to do some writing. In each case you should think about why the activity is included in the book. If you can figure out some good purposes for an activity, you will learn more from doing the activity.

You might ask, "Why not just tell us the purpose of an activity?" The answer is, you will learn more if you figure it out for yourself. Most likely you will figure out purposes that are important to you. You will figure out purposes that the author did not think of. The "figuring out" process will help you to get better at thinking and problem solving.

All of the activities in this first chapter can be done mentally, just by making up answers in your head. All can be done by talking with other students in your class and sharing answers you have thought about. Thinking and talking are good ways to learn. All can be done by writing in your journal. Writing is a very powerful aid to learning.

It is particularly important that you do the first activity as a journal-writing activity. Each chapter contains a similar activity.

The second activity in each chapter is a "talking" activity. You can learn a lot by talking about the ideas that you want to learn. The third and fourth activities ask you to make up some short quizzes and try them out on others in your class. You can learn a lot by figuring out what you think are the important ideas that a quiz might cover.

CHAPTER 1 SUMMARY

Here are four good ways to get better at problem solving:

1. Learn reading, writing, and arithmetic.
2. Learn a number of general purpose strategies for solving problems.
3. Learn to use tools, such as the computer, that help solve problems.
4. Practice solving problems.

Activities

1. Pick some idea that you thought about while reading this chapter. Perhaps you thought about how the world is changing. Perhaps you thought about how much you are learning in school—and that there seems to be a great deal to learn. Perhaps you thought about ways in which you are already very good at problem solving. Write several paragraphs in your journal about some idea that you thought about. You might want to use the outline given below.

    1. Make a title for this journal entry. Your title might look like this:

    CHAPTER 1 ACTIVITY 1
    AN IDEA I HAD WHILE I WAS READING CHAPTER 1

    2. Write down and explain the idea.

    3. Explain why the idea interests you. Why did you remember this idea?

    4. How does this idea relate to things that you do outside of this class?

    5. What else do you think about when you think about this idea?

2. Get together with two or three other students in the class. Each of you is to select one idea from this chapter that seems particularly important to you. Each of you is to spend a minute or two talking about the topic.

Why did you select it? Why is it important to you? What difference does it make in your life?

In talking about your topic, try to make use of some of the new terms introduced in this chapter. A list is given below. Remember, definitions are given in the Glossary.

advance organizer
basic skills
higher-order thinking skills
Information Age
lower-order thinking skills
strategy

3. Make up a short quiz of lower-order thinking skill questions for this chapter. Include correct answers with your questions. Try out your quiz on two students in your class. Here are a three examples of lower-order thinking skill questions.

   A. When did the Information Age begin in the United States? (If your answer is within five years of the exact date, it will be considered to be correct.)

      Answer: 1956

   B. Name at least three tools that people use to help solve transportation problems.

      Answer: Airplane, bicycle, car, skateboard, train.

   C. True False A *strategy* is a plan that will solve any problem.

      Answer: False.

4. Make up a short quiz of higher-order thinking skill questions for this chapter. Think about possible answers. Try out your quiz on two students in your class. Here are two examples of higher-order thinking skill questions.

A. In an Information Age, more people have information and service jobs than have manufacturing jobs. How does this affect what students should learn in school to help prepare them for life in an Information Age society?

B. A steam engine is a tool that helps the human body do physical work. A hand-held calculator is a tool that helps the human mind do mental work. Give two more examples of tools that help the human mind. Then discuss how the development of tools that aid the human mind affects education.

5. You know that it is important to learn how to write. People have developed various tools to help them write. Examples include the typewriter, ball point pen, and word processor. In what ways is a word processor a more powerful aid to writing than a ball point pen or a typewriter? In what ways is it not as good?

6. One part of this chapter talks about memorizing facts and learning to think using the facts. Both are important. Which seems more important to you? (Explain why.) Which are you better at?

7. There are lots of ways to get better at problem solving. This chapter suggests several. Here are a few more:

   A. Practice making up problems.

   B. Learn a lot about a subject—this will help you in solving problems in that subject.

   C. Develop a positive attitude and self-confidence.

   D. Learn to work hard and to keep trying.

   Add several more items to the list. Then decide which ones are best for you. Are these same ones also best for other people you know? If you were going to pick just one to really get better at, which one would you pick? Why?

8. Think of someone you know who is a very good thinker. How do you know this person is a very good thinker? (How can you tell? What does this person do that helps you know he or she is a good thinker?)

Chapter 2
You Are a Smart Person

ORGANIZE YOUR THINKING

The ability to think before you act is very important in solving problems. Most people are good at considering alternatives. This chapter is about:

- What it means to be "smart."
- Thinking about your own thinking.
- Thinking about what kinds of problems are easy for you.

You Are Smart

This book can help you get smarter. We will begin this chapter with a short quiz. Most likely you will do really well on this quiz. This will show that you are quite smart. It will show that you are smart enough so that this book can help you get smarter.

You will need to use your journal. Start by thinking about some things that you do for fun outside of school.

Begin ✍✍ (Please write in your journal.)

1. Make a title for this journal entry. Your title might look like this:

   FUN THINGS THAT I MIGHT DO AFTER SCHOOL TODAY

2. Make a list of three different things that you might do after school this afternoon or evening that would be fun.

3. Next, underline the one of these three things that you feel would be the *least* fun.

4. Finally, write down a possible replacement for the item that you have underlined. Write down something that you feel would be more fun and that is not already on your list.

End ✍✍

That's it. That's the whole quiz. You passed if you were able to do what it asked you to do. Did you think that this was a hard quiz? What was hard about it? What was easy about it? Did the idea of taking a quiz scare you?

To pass the quiz, you had to know how to read, write, and follow directions. You needed to think about what might happen in the future. You needed to create an alternative to what might happen. A person who can do all of these things is quite smart.

What Does It Mean to Be Smart?

It is not easy to define the word "smart." It is even harder to make up a good test to see how smart someone or some creature is. Perhaps you have a pet cat or dog that seems rather smart to you. Do you think a cat or dog can plan alternative activities about what it might do later in the day? How would you test this?

Begin ✍✍ (You may want to write in your journal.)

Respond to some of the questions about being smart. How can you tell if a cat is smart? Do cats plan their day in advance? How could you tell?

Make up a definition of what it means to be a smart person. Remember, you are a smart person. You should satisfy your own definition of being a smart person.

End ✍✍

In this book we will use a simple definition of a **smart person**.

> You are a smart person if you can understand and can solve a number of the problems you encounter. The more of these problems you can solve, the smarter you are. A smart person can solve lots of different

kinds of problems. A smart person can solve hard problems and can learn to solve new problems.

This definition says that how smart you are depends on how good you are at solving problems. Researchers have discovered lots of ways to help people get better at solving problems. This book contains many of their ideas. You will find that these ideas are easy to learn and easy to use. Thus, this book will help you become smarter.

Sometimes the problem you must solve involves decision making: "What should I wear today?" "What should I have for lunch today?" "What book should I read for my social studies project ?" In decision situations, you can think about different possibilities. You can imagine what might happen from each decision. You can make a decision on what outcome seems best. This is an important type of problem solving.

Different Kinds of Problems

There are many different kinds of problems. For example, there are problems in dealing with your friends. There are problems about how to get to some place in town and home again without getting lost. There are problems that have to do with doing well in sports. There are problems that have to do with school subjects, such as math, science, and language arts. There are problems that have to do with playing games, such as Monopoly and chess. There are problems in dealing with technology, such as telephones, stereos, and computers. There are problems in dealing with the types of change going on in our Information Age society.

A person might be very good at dealing with one type of problem and not so good at dealing with another type of problem. For example, a person might be very good at solving chess problems and not very good at dealing with people problems. A person might be very good at dealing with school problems and not very good at dealing with problems outside of school. A person might be very good in music and not so good in sports.

Think about this for yourself. Are you better at solving "school" problems or at solving "people" problems? Are you good at finding your way to new places and not getting lost? Are you better at music or sports? Are you good at being popular? Are you good at organizing your activities and keeping your locker clean and neat?

Remember, writing in your journal is very important. You will learn much more if you regularly write in your journal. As you write, think about

what you are writing. Clear thinking and clear writing are closely connected!

Please do the following journal-writing activity. You will use the results later in this chapter and in the next chapter.

Begin ✍✍ (Please write in your journal.)

1. Make a title for this journal entry. Your title might look like this:

   _____

   IMPORTANT PROBLEMS THAT ARE EASY FOR ME

2. Write down a type of problem that is important to you and that you are good at solving. One way to do this is to think first of a specific example of a problem you have solved. For example, maybe you saved money to buy a neat new outfit. Then think of the general problem that this suggests. For example, perhaps you are good at solving the general problem of budgeting your money.

3. Now think of another type of problem that you are good at solving. Pick one that is a whole lot different from your first type of problem. For example, you might think about a new friend you made yesterday. This would help you to think about how good you are at making new friends. Being good at making new friends is a lot different from being good at budgeting your money.

End ✍✍

Thinking About Thinking

Educators have done a lot of thinking about how to help students get better at solving problems. They have come up with many good ideas. Schools are designed to help students learn some of these ideas.

One of the very best ideas is thinking about thinking. Remember the quiz at the beginning of this chapter? In it you had to think about what you might do after school and this evening. You then had to think about which of these things would be the least fun. You were thinking about thinking!

Thinking about thinking is so important that there is a special word for it. It is called **metacognition**. If you practice thinking about thinking—if you practice metacognition—you will get better at thinking and problem solving.

In the journal-writing activity IMPORTANT PROBLEMS THAT ARE EASY FOR ME, you were thinking about kinds of problems you are good at solving. You were thinking about your own problem-solving skills. You were doing metacognition. Look back at what you wrote in your journal. Think about what you wrote. Do some more metacognition.

When you are listening to your teacher talk, your mind sometimes wanders. You begin to think about something else, such as meeting a friend for lunch. Then you think to yourself, "I wonder what the teacher said that made me think about meeting my friend for lunch?" You are thinking about your own thinking. You are doing metacognition.

Let's practice doing metacognition. This is a journal-writing exercise.

Begin ✍✍ (Please write in your journal.)

1. Make a title for this journal entry. Your title might look like this:

   _____

   PRACTICE IN METACOGNITION

2. Go back and read your journal entry with the title IMPORTANT PROBLEMS THAT ARE EASY FOR ME.

3. How are these problems alike? Make a brief list of how these problems are alike.

4. How are these problems different? Make a brief list of how these problems are different.

5. Now write several sentences about why these problems are easy for you to solve.

End ✍✍

CHAPTER 2 SUMMARY

Metacognition—thinking about thinking—is very important. You can think about your own thinking. This is one way to get better at solving problems. Some other key ideas in this chapter include:

1. You know some types of problems that you are good at solving.

2. You can think about why some problems are easier for you than other problems.

Activities

1. Pick some idea that you thought about while reading this chapter. Perhaps you thought about why you are good at some things and not so good at others. Perhaps you thought about day dreaming and whether day dreaming is like metacognition. Perhaps you thought that thinking about thinking makes your brain dizzy. Write several paragraphs in your journal about some idea that you thought about. You might want to use the outline given below.

    1. Make a title for this journal entry. Your title might look like this:

    CHAPTER 2 ACTIVITY 1
    AN IDEA I HAD WHILE I WAS READING CHAPTER 2

    2. Write down and explain the idea.

    3. Explain why the idea interests you. Why did you remember this idea?

    4. How does this idea relate to things you do outside of this class?

    5. What else do you think about when you think about this idea?

2. Get together with two or three other students in the class. Each of you is to select one idea from this chapter that seems particularly important to you. Each of you is to spend a minute or two talking about the topic. Why did you select it? Why is it important to you? What difference does it make in your life?

In talking about your topic, try to make use of some of the new terms introduced in this chapter. A list is given below. Remember, definitions are given in the Glossary. Also, look back at the list of new terms given in the previous chapter. Use some of them in your discussion.

metacognition
smart person

3. Make up a short quiz of lower-order thinking skill questions for this chapter. (Include correct answers. Often a lower-order skill question has only one correct answer.) Your quiz should consist of questions that can be answered by a person who has a low level of knowledge of the material in this chapter.

   Then try out your quiz on two students in your class.

4. Make up a short quiz of higher-order thinking skill questions for this chapter. (Think about some possible correct answers. Remember that a good higher-order skill question is likely to have many different correct answers.) Your quiz should consist of questions that can be answered by a person who has a good understanding of the material and ideas in this chapter.

   Then try out your quiz on two students in your class.

5. Is a book smart? In some sense, a book "knows" a lot of facts. A large dictionary "knows" the spelling and definitions of a lot of words. Write several paragraphs in your journal about the question "Is a book smart?" You might want to use the outline given below.

   1. Make a title for this journal entry. Your title might look like this:

CHAPTER 2 ACTIVITY 5
IS A BOOK SMART?

   2. Write a paragraph that argues that a book is smart.

   3. Write a paragraph that argues that a book is not smart.

   4. Write a paragraph that contains your own personal conclusions.

6. Is a machine smart? For example, think of an elevator. As people get on, they push the button of the floor where they want to get off. The elevator is "smart" enough to arrange these requests in a logical order and then to stop at these floors.

   Or consider a calculator. If you want to multiply two numbers, you just key in the numbers and the calculator "knows" how to do the multiplication. It can do it rapidly and without error. If a person can do multiplication rapidly and without error, we say the person is "smart" at doing multiplication.

   Write several paragraphs in your journal about the question "Can a machine be smart?" You might want to use the outline given below.

   1. Make a title for this journal entry. Your title might look like this:

   CHAPTER 2 ACTIVITY 6
   CAN A MACHINE BE SMART?

   2. Write a paragraph that argues that a machine can be smart.

   3. Write a paragraph that argues that a machine cannot be smart.

   4. Write a paragraph that contains your own personal conclusions.

7. In the journal-writing activity IMPORTANT PROBLEMS THAT ARE EASY FOR ME, you gave some examples of problems that were easy for you to solve. Here the task is to think of examples of problems that are hard for you.

   1. Make a title for this journal entry. Your title might look like this:

   CHAPTER 2 ACTIVITY 7
   IMPORTANT PROBLEMS THAT ARE HARD FOR ME

   2. Write down a general type of problem that is important to you and that you are not good at solving. One way to do this is to think of a specific example of a problem you tried to solve but did not solve. For example, you may have bought junk food and gone to a movie with the money you were saving to buy a new sweater. Then figure out what the general problem is. In the example here, perhaps the general problem is that you are not good at saving money.

3. Now think of another type of problem you are not good at solving. Pick one that is a whole lot different from your first type of problem. Perhaps the problem is that you are not good at singing on key.

8. This activity assumes that you have done Activity 7. In that activity you thought about two types of problems that are hard for you. Here we want you to think about what makes these types of problems hard for you.

    1. Make a title for this journal entry. Your title might look like this:

CHAPTER 2 ACTIVITY 8
METACOGNITION ON HARD PROBLEMS

    2. How are your two problems from Activity 7 alike? Make a brief list of how the problems are alike.

    3. How are your two problems different? Make a brief list of how the problems are different.

    4. Now write several sentences about why these problems are hard for you to solve.

9. Write on the topic of arguments for and against the statement that a person gets smarter by going to school. We suggest that you do this as follows.

    1. Start your journal entry with the following title:

CHAPTER 2 ACTIVITY 9
GETTING SMARTER BY GOING TO SCHOOL

    2. Give arguments that you believe show that one can get smarter by going to school.

    3. Give arguments that you believe show that one cannot get smarter by going to school.

    4. Summarize your personal opinion. Base this on how you feel and think about the ideas you have written.

    If you have enough time, also write on:

5. Some way to gather more evidence that would support 2.

6. Some way to gather more evidence that would support 3.

10. A good thinker can argue both sides of a question. A good thinker can understand another person's point of view. You can get better at thinking by practicing arguing both sides of an issue.

    Think about the last time you had an argument with someone. Make a list of arguments for both sides. Try really hard to make a good list for the other person! What is your best argument? What is your weakest argument? What is the other person's best argument? What is the other person's weakest argument?

Chapter 3
What Is a Problem?

ORGANIZE YOUR THINKING

This chapter contains a four-part definition of the word "problem." This definition is used throughout the rest of the book. A starting point in solving a problem is to gain a clear statement of the problem. This chapter will give you practice in:

- Using metacognition to understand the meaning of "problem."
- Dealing with problem situations that are not clearly defined problems.
- Using brainstorming as a useful strategy in dealing with problem situations.

What Does the Word "Problem" Mean to You?

The first two chapters discussed problems and getting better at solving problems. You thought about examples of some types of problems that you find easy to solve. It is clear that you sort of understand what the word "problem" means. You have no trouble using it correctly when you talk and write. But do you think that the word "problem" means the same thing to all people?

This is important. Suppose that the word "problem" has a quite different meaning to you than it does to the author of this book. You and the book will then be at odds. You will be expecting things that the book is not intended to do. Similarly, suppose that the word "problem" means different things to your teachers than it does to you. This will cause trouble when they try to help you learn about problem solving.

This chapter has one main goal. The goal is to help you learn the definition of the word "problem" as it is used in this book. It is the definition used by most authors of books on problem solving. The rest of this book assumes that you understand and will use this definition.

What Is Your Definition of a Problem?

Pat is a student in a school like yours. Think about Pat encountering a number of **problem situations** during the day. These are situations that concern or disturb her. They are situations that Pat might try to do something about. She might do something that would change the situation. But in these problem situations Pat does not see an immediate course of action. She doesn't know what to do that will resolve the situation. Pat would need to do some thinking in order to decide on a course of action.

Pat's Problem Situations

1. Pat wakes up in the morning and remembers that it is a school day. Pat thinks, "Most of my clothes are dirty. What should I do?"

2. At breakfast, the television set is on. Pat hears the announcer talking about an African country: "The situation is grave. It is reported that 5,000 children are starving." Pat finds that it is hard to eat while thinking about these starving children.

3. Pat enters the front door of the school just as the bell rings for first period. Pat thinks, "If I go to my locker and get the books for my first class, I'm going to be tardy. What should I do?"

4. The teacher in Pat's second period gives a very long homework assignment. Pat thinks, "I don't have time to get it done during study hall. What shall I do?"

5. In Pat's science class, the teacher tells the students to do the first three problems on page 98. Pat looks at the first problem and thinks, "I don't understand this problem. What am I going to do?"

6. In talking to a close friend, Pat says, "This guy wants to meet me at the game tonight. What do you think?"

7. Pat's social studies teacher is talking about drunk driving. The teacher says, "Last year in this country about 25,000 people died because of drunk drivers." Pat thinks about her older brother's friend who drinks and drives. She feels scared.

As you read about Pat's problem situations, they may suggest some of the kinds of problem situations you have. Think about the kinds of problem situations you encounter day to day. Then think about the ways in which they are alike. In what ways are they different?

As you think about various problem situations in your life, you may begin to see common patterns. In some ways, all problems have certain characteristics in common. The following journal-writing activity will help you understand what the word "problem" means to you and to other people.

Begin ✍✍ (Please write in your journal.)

1. Make a title for this journal entry. Your title might look like this:

   _____

   MY DEFINITION OF "PROBLEM"

2. Write down what the word "problem" means to you. Write your definition so that other students in your class will understand what you mean.

3. Next, get together with two or three other students. Each student is to read his or her definition out loud and explain what it means.

4. Then your whole group is to work together to make up a definition. Make one you can all agree on. It should include all the key ideas that each group member has thought of. Write this definition in your journal. Or your teacher may provide each group with a large sheet of paper and a marking pen. Then you can write your group's definition on the paper and post it for the whole class to see.

End ✍✍

The above exercise has three purposes. First, it gives you a chance to clarify your thoughts on what "problem" means to you. Writing is a very important aid to problem solving. Writing *helps* your brain to think. Writing *requires* your brain to think. It helps you organize and clarify your thoughts on a problem.

Second, the exercise gives you a chance to work with other students. You get to hear what they are thinking. You learn how their minds work. It is interesting to learn that people think in different ways. There is no one "right" way to think.

Third, the exercise gives you a chance to work in a group to accomplish a task. Working together in groups is a very important approach to solving problems. Working in groups is also a good way to learn. It is called **cooperative learning**. Working in groups is so important that we will suggest a number of cooperative learning activities in this book.

By now you should realize that it is not easy to give a good definition of the word "problem." In this next section we will study a sample problem. We will point out some of its key features. These key features are part of every problem.

Halloween Costume Day at School

Terry is a student in a school like yours. Here is a problem situation that Terry has:

> Next Thursday is Halloween. The students and teachers have talked about it. They have decided to make it a costume day. Everybody is encouraged to dress up. Some students have indicated they will dress up as a Wizard of Oz character. Some will be characters from other books. Others will wear masks or funny makeup. The students and teachers suggested that no one should spend more than $12 on his or her costume.

Terry had to decide what to do about Halloween day at school. She is very careful and methodical in her thinking. She knows a lot about problem solving. She organized her thinking into four parts and wrote notes to herself about each part. This is what she wrote:

1. **The given situation**: Halloween is next Thursday. This is a regular school day, but it will also be costume day. Many students and teachers will be wearing costumes.

2. **My goal**: I must get a costume to wear to school next Thursday.

3. **Resources and Restrictions**: I can think of a number of things I might do. For example:

   A. (A Resource): My mother has some old clothes she wore when she was young. Maybe some of these old things would be useful to me.

B. (A Resource and a Restriction): I have about $10 saved up. This is less than the $12 maximum that a person is allowed to spend. I could use the money to buy a part of a costume.

C. (A Resource): I have a costume I used in a parade a few months ago. It still fits.

D. (A Resource): I have several friends who might loan me a costume.

E. (A Resource): I am creative. I might make a costume.

F. (A Resource): I am a good thinker. I might use two or more of the above ideas together.

G. (A Restriction): But I don't want my costume to be too elaborate.

H. (A Restriction): I don't have much time to work on getting a costume.

4. **Importance to me:** Dressing right for Halloween costume day is very important to me. All of my friends will be wearing costumes. I want to be part of the group. I don't want to stand out as being different.

All of Terry's writing and brainstorming didn't solve the problem. But it organized the problem into four main parts. The problem is now carefully defined. Each of the four main parts seems clear to Terry. Terry was doing **problem posing**. Problem posing is making up a clearly defined problem. Problem posing requires very careful thinking. It is the starting point for resolving a problem situation.

In some sense, each person in the school is faced by the same problem situation. Each person must decide what to wear on Halloween day. But the details are probably different for each person. The same problem situation (Halloween costume day) creates different problems for different people. Each person must do his or her own problem posing.

Begin ✍✍ (You may want to write in your journal.)

Where do problems come from? Who makes up most of the problems you must deal with? Give several examples of problems you have posed for yourself so far today. Have you managed to solve each of these problems? Are there some problems that cannot be solved?

Which would you rather work on solving, and why?

A. A problem that a teacher or a school book gives to you?

B. A problem that you pose for yourself?

End ✍✍

A Formal Definition of "Problem"

Many people have thought about problem solving. A number of people have written books about problem solving. They have done the types of metacognition and group exercises you did earlier in this chapter. Their work has led to the following four-part definition of the word "problem." This is the definition we will use in the rest of the book.

A problem has four parts. The four parts are listed below. As you read the four parts, compare what is written here with the Halloween costume-day example given above. Each part of this definition is illustrated in Terry's example.

1. **Givens**. There is a given beginning situation. This is a description of how things are, what is happening, what is known, and so on. It is a statement of the facts of the problem situation.

2. **Goal.** There is a desired final situation. This is a description of how you want things to be. What do you want to accomplish? How can you tell if the problem has been solved?

3. **Resources and Restrictions**. What can you do that will affect the situation? What types of things can you do that might help you achieve the goal? What resources do you have? Resources include skills, knowledge, time, energy, materials, machines, money, and so on.

What are the restrictions and rules you must follow in working to solve the problem? Often these are not written down, but you know them—for example, YOU SHOULD NOT BREAK THE LAW, or in taking a test, DO YOUR OWN WORK.

Notice that Resources and Restrictions are not "how to solve the problem." A problem might not be solvable, and yet it could have resources and restrictions.

4. **Ownership—importance to you.** In order for something to be a problem for you, you must have some interest in it. You must accept some ownership. You must want to solve the problem and agree to work on it. Notice that in some cases you may be only mildly interested. In other cases you may be deeply interested.

Begin ✍✍ (Please write in your journal.)

In Chapter 2 you were asked to do a journal-writing activity on IMPORTANT PROBLEMS THAT ARE EASY FOR ME. Probably you wrote very brief descriptions of the problems. Now we want you to rewrite at least two of these problems. As you do so, clearly identify the four distinct parts of each problem. An example is given below. Please follow its format.

1. Start your journal entry with a title line for the problem:

I AM GOOD AT DOING MENTAL ADDITION PROBLEMS

2. The four parts of this type of problem are:

   Givens: I am given any two positive whole numbers that are not more three digits long.

   My goal: To quickly find the sum.

   Resources and restrictions: I must do it in my head. I am not allowed to use a calculator or pencil and paper. (Note: Once again, notice that resources and restrictions are *not* a set of steps on how to solve the problem.)

Ownership—importance to me: I am good at this type of problem. It makes me happy to be able to add numbers quickly and accurately in my head. It impresses my friends. I find it is useful in doing other types of math problems.

End ✍✍

A Clearly Defined Problem

A number of people have written books about problem solving. They all agree on two things. First, to solve a problem you must have some level of interest or ownership. It takes energy and thought to solve a problem. Suppose your response to a problem situation is, "I couldn't care less." Then you will not spend time on it. You will not solve the problem.

Second, experts on problem solving agree that you must understand a problem in order to solve it. What they mean is that you must have a pretty good understanding of the givens, goal, and resources and restrictions. If all of these are quite clear, we say that the problem is a **clearly defined problem.** If they are not clear, we say that the problem is a **poorly defined problem**. Most real-world problem situations are not clearly defined problems. Thus, the starting point in dealing with most real-world problem situations is to first pose a clearly defined problem.

Let's take an example. Earlier in this chapter we listed a number of problem situations Pat encountered during the day. One of them was:

2. At breakfast, the television set is on. Pat hears the announcer talking about an African country: "The situation is grave. It is reported that 5,000 children are starving." Pat finds that it is hard to eat while thinking about these starving children.

Compare this with the four parts of a problem. Pick out the parts that are clear.

1. **Givens**: "The situation is grave. It is reported that 5,000 children are starving."

2. **Goal**: Notice that no goal is stated. This is often the case in real-world problem situations.

3. **Resources and restrictions**: Notice that no resources and restrictions are stated.

4. **Ownership—importance to Pat**. We are told that "Pat finds that it is hard to eat while thinking about these starving children." This suggests that Pat is concerned. She would like to do something about this situation.

Suppose Pat decides she is strongly interested in doing something about the situation. Then she should work to get a more clearly defined problem. She must pose a problem that she wants to solve.

There are many possible clearly defined problems that can come from this problem situation. Pat needs to decide on a goal. For example, Pat might think about goals such as the following:

2A. Goal: To provide food to some of the African children who are starving.

2B. Goal: To find out why the African country does not have enough food.

2C. Goal: To provide food for some of the people in my town who do not have enough to eat.

2D. Goal: To cut down on the waste of food that I see going on in the lunch room.

Notice how different these goals are, even though each is related to the given situation. There are many other possible goals that might occur to Pat. Pat may think of more goals as she continues to work on this problem situation.

Even after Pat selects a goal, she still does not have a clearly defined problem. She still needs to think about resources and restrictions. For example, suppose she selects the third goal:

2C. Goal: To provide food for some of the people in my town who do not have enough to eat.

Now Pat can begin to think about resources and restrictions that relate to the givens and this goal. As noted in our four-part definition of a problem, often many of the restrictions are not stated. For example, there is no need

for Pat to write down that she should not steal to get money to buy food for the needy. Pat might make a list such as the following:

3. Resources and restrictions:

   A. (Resource): I am good at organizing things. I could organize a food drive.

   B. (Possible Restriction): I remember that our school had a food drive last year. But there was a big argument about who the food was to be for. I think this means it is okay to have a food drive at our school. I could check with the school principal on this.

   C. (Resource): I have a lot of friends. I think I could get my friends to help.

   D. (Resource and Restriction): I am not very busy after school. I could put in two hours each day for the next month. But I am very busy on the weekends. I don't have any free time then.

   E. (Resource): I think my social studies teacher would be interested in this problem. I could probably get some help from him.

   F. (Resource): My sister has a friend who has a truck. Perhaps we could use that truck.

Now Pat has posed a clearly defined problem. She can begin to think about things she might actually do. What is the best way to reach the goal? As Pat thinks about what she will do, she may get more ideas that fit into the category of resources and restrictions. She might even change her mind and pick a different goal. Remember, Pat posed the problem. She is free to pose a different problem.

Begin ✍✍ (You may want to write in your journal.)

Think about one of the other goals that occurred to Pat. Suppose Pat had picked this other goal. Would the same list of resources and restrictions still apply? Think about some resources and restrictions Pat might have for this

new goal. Pretend you are Pat and write down a list of resources and restrictions.

End ✍✍

Brainstorming as an Aid to Posing a Clearly Defined Problem

It often happens that a problem is not clearly defined because the goal is not clear, or the resources and restrictions may not be clear. A good way to begin work on gaining clarity is through **brainstorming**. In brainstorming, the thing to do is to write down a lot of ideas without criticizing them. Write down whatever comes to mind. Do not spend time thinking about whether an idea is good or not so good. The task is to quickly produce a long list. Brainstorming is fun.

At the beginning of this chapter we listed seven of Pat's problem situations. We called them problem situations because they were not clearly defined problems. They were situations that concerned Pat. However, the givens, goal, and resources and restrictions were not clearly stated.

Select one of Pat's problem situations. Mentally, or using writing, brainstorm a list of possible goals. Once a goal is selected, brainstorm a list of resources and restrictions. You can do this brainstorming all by yourself. Or a group of people can brainstorm together. Brainstorming is a useful strategy. It is a strategy that can be used on different parts of getting a clearly defined problem.

Begin ✍✍ (Please write in your journal.)

Consider the last item on Pat's list of problem situations.

> Pat's social studies teacher is talking about drunk driving. The teacher says, "Last year in this country about 25,000 people died because of drunk drivers." Pat thinks about her older brother's friend who drinks and drives, and she feels scared.

1. Start your journal entry with a title line for this problem situation:

PAT'S PROBLEM SITUATION OF DRUNK DRIVERS

2. First work all by yourself. Brainstorm possible goals Pat might have in this problem situation. See if you can make up a half dozen different goals.

3. Now get together with two other students in your class. Compare your lists of goals. The three of you should select one goal you would like to talk about some more.

4. The three of you should do a group brainstorm on resources and restrictions related to the goal you have selected. You might have just one person do the writing. Or each of you might want to write down all of the ideas in your journal. Remember, don't be critical of others' ideas!

End ✍✍

Precise Communication of Problems

Many problem situations are too big for one person to resolve all alone. You know about environmental issues, such as air pollution, oil spills, and dealing with nuclear wastes. These are very big problem situations. When many people are going to work on a problem together, it is very important that the problem be clearly defined. Otherwise, the people may end up working at cross purposes with each other. For example, they may select different goals.

When a problem is clearly defined, it can be communicated to others. Work on solving it can be done by a number of people. They may even be located in different countries or live at different times. It may take many years for a problem to be solved.

Medical problems provide very good examples. There are medical researchers in many different countries. Suppose a researcher in some foreign country learns how to cure a disease. Then doctors in your country can learn to use the same treatment process.

A clearly defined problem might be broken into a number of pieces, with different people working on different pieces. A good example is provided by all of the people now working on environmental issues. They know we live in a global village. They know that pollution from one country can

affect people in another country. Each country must be involved in working on this problem.

We will come back to this idea in Chapter 10 where we talk about computer programming. A **computer program** is a set of directions telling a computer what to do. The directions must be written so that a computer can understand them, that is, so that a computer can do what the directions say to do.

Suppose you are communicating with a computer. You are telling the computer what you want it to do. But you do not use precise communication. The computer cannot read your mind. It cannot know what you mean by "you know" and the body language people use when talking. Precise communication is essential in writing computer programs.

CHAPTER 3 SUMMARY

A problem has four parts: Givens, Goal, Resources and Restrictions, and Ownership. A problem is said to be clearly defined if the givens, goal, and resources and restrictions are all quite clear.

Most problem situations are not clearly defined problems. This is especially true of real-world problem situations. It can take a lot of thinking to get a clearly defined problem from a problem situation. Brainstorming is often a useful strategy in this thinking process.

If a problem is clearly defined, it can be communicated to others. This allows groups of people to work together to solve the problem. It allows the problem to be broken into pieces so that different people can work on the different pieces.

Activities

1. Pick some idea you thought about while reading this chapter. Perhaps you thought about how school problems seem to be different from problems outside of school. Perhaps you thought about how it is fun to talk about school subjects to other people in the class. Write several paragraphs in your journal about some idea you thought about. You might want to use the outline given below.

1. Make a title for this journal entry. Your title might look like this:

CHAPTER 3 ACTIVITY 1
AN IDEA I HAD WHILE I WAS READING CHAPTER 3

2. Write down and explain the idea.

3. Explain why the idea interests you. Why did you remember this idea?

4. How does this idea relate to things you do outside of this class?

5. What else do you think about when you think about this idea?

2. Get together with two or three other students in the class. Each of you is to select one idea from this chapter that seems particularly important to you. Each of you is to spend a minute or two talking about the topic. Why did you select it? Why is it important to you? What difference does it make in your life?

   In talking about your topic, try to make use of some of the new terms introduced in this chapter. A list is given below. Notice that this list is longer than the list from the first two chapters. This chapter contains many ideas that may be new to you. Remember, definitions are given in the Glossary.

   brainstorming
   clearly defined problem
   computer program
   cooperative learning
   given initial situation
   goal
   ownership
   poorly defined problem
   problem
   problem posing
   problem situation
   resources and restrictions

3. Make up a short quiz of lower-order thinking skill questions for this chapter. (Include correct answers. Often a lower-order skill question has only one correct answer.) Your quiz should consist of questions

that can be answered by a person who has a low level of knowledge of the material in this chapter.

Then try out your quiz on two students in your class.

4. Make up a short quiz of higher-order thinking skill questions for this chapter. (Think about some possible correct answers. Remember that a good higher-order skill question is likely to have many different correct answers.) Your quiz should consist of questions that can be answered by a person who has a good understanding of the material and ideas in this chapter.

   Then try out your quiz on two students in your class.

5. You are talking to a close friend. Your friend says, "I'm bored. I don't know what to do this evening." Brainstorm a list of suggestions for your friend. Do this in your journal, using a title line such as:

   CHAPTER 3 ACTIVITY 5
   BRAINSTORMING ABOUT BEING BORED

6. Most likely you have been faced by the situation in which a number of your teachers each give you a long homework assignment due the next day. Imagine that tomorrow this is going to happen to you. Work on this problem situation in your journal, using a title line such as:

   CHAPTER 3 ACTIVITY 6
   BRAINSTORMING ABOUT TOO MUCH HOMEWORK

   1. Brainstorm a list of goals you might consider in this problem situation.

   2. Then select one of the goals from your list. Brainstorm on resources and restrictions related to this goal.

   3. Next, pick a different goal from your list. Brainstorm resources and restrictions for this goal.

7. Environmentalists are concerned about acid rain. Think of this issue as a problem situation that concerns you. Develop two quite different, clearly defined problems having to do with acid rain and you. That is, think of two different goals. For each goal, think of a list of resources

and restrictions. Remember that resources and restrictions are *not* a set of directions on how to solve a problem.

8. Environmentalists are concerned about global warming. Think of this as a problem situation that concerns you. Develop two quite different, clearly defined problems having to do with global warming and you.

9. Is it possible that a person has a clearly defined problem but the problem cannot be solved? Give good arguments to support your answer. (A very good argument on one side of this question would be to give an example of a clearly defined problem that has no solution.)

10. There are many different definitions of the word "problem." For example, the Cardinal edition of the *Merriam-Webster Pocket Dictionary* gives the following definition for "problem":

    1 Something to be solved.
    2 Something difficult to understand.

    The purpose of this activity is to compare and contrast several different dictionary definitions of the word "problem."

    1. Make a title for this journal entry. Your title might look like this:

    CHAPTER 3 ACTIVITY 10
    DICTIONARY DEFINITIONS OF "PROBLEM"

    1. Write down the definitions of "problem" from two or three different dictionaries.

    2. Write a couple of sentences about how the definitions are alike.

    3. Write a couple of sentences about how the definitions are different.

    4. Give your opinion on why there are so many different definitions of "problem."

11. Why do we have laws? Think about some type of laws, such as traffic laws. Explain what problem is being addressed by these laws. To do this, you might want to give two different examples of clearly defined traffic problems. Explain how traffic laws help solve these problems.

Chapter 4
A Four-Step Plan for Solving a Problem

ORGANIZE YOUR THINKING

How do you get started in solving a problem you don't know how to solve? One way is to get a clear understanding of the problem. Then devise a plan of action, carry out the plan of action, and check to see if you have solved the problem.

Some other key ideas in problem solving include:

- Don't reinvent the wheel. Make use of previous work that you and others have done.

- School helps you to get better at solving problems. Each school subject focuses on how to solve the problems of its subject area.

Introduction

Chapter 3 presented the idea of a problem situation that concerns or disturbs you. It is a dissonance that prompts you to action. When you encounter a problem situation, you need to decide what to do. You may begin by posing a clearly defined problem.

But what do you do next? The problem still remains unsolved. Is there some easy way to solve every clearly defined problem?

Unfortunately, the answer is no. Some problems are very hard. There are problems people have worked on for years. Indeed, some clearly defined problems have no solution. They are called **unsolvable problems**. As a simple example, consider the problem of finding two positive numbers whose sum is a negative number. This is a clearly defined math problem, but it has no solution.

However, many of the problems you encounter can be solved. You can get better at solving them through study and practice. This chapter suggests two general approaches to getting better at solving problems.

1. Learn some general ways to attack problems. This chapter gives a four-step plan that is useful in attacking a wide range of problems. (Chapter 5 gives some other general purpose methods for attacking problems.)

2. Learn to build on the work of other people. Each subject you study in school contains some of the work of other people. Each subject has already been studied for many years by experts in that field. The experts have picked out some of the most important ideas. When you learn these ideas, you are building on the work of these experts.

A Four-Step Plan for Attacking a Problem

Many researchers have studied how people solve problems. They study people who are very good at solving problems. They do metacognition. They study how the human mind works as it solves problems.

Researchers have learned a great deal about how to solve problems. They have learned that there is no one method that will always work. But they have identified one general plan that is very useful. It is a way to get started on almost any problem. It has four steps, so it is called the **four-step plan for solving a problem.** The four steps are:

1. Understand the problem.

2. Devise a plan of action.

3. Carry out the plan.

4. Check to see if the problem is solved. See if new problems have been created.

You should memorize this four-step plan and practice using it. Learn when it is useful to you and when it is not useful. Remember, its purpose is to help you get started on a hard problem. There is no guarantee that you will succeed in solving the problem even with this help in getting started.

A Problem-Solving Example

In this section we give an example of using the four-step plan for solving a problem. In the next section we give more detail on each of the four steps.

> Dave shares a bedroom with his younger brother Tom. Their mother is angry because the room is so messy. She says, "Dave, you are five

years older than Tom. You are old enough to take responsibility for your room. I want you to see that the room is kept neat and clean. I think that Tom should help." Dave feels a little guilty about how messy the room is. He realizes that he has been setting a bad example for his younger brother.

Dave has a problem situation. He decides to use the four-step plan to attack this problem situation.

1. Understand the problem. (This first step uses the ideas of Chapter 3.)

1. Givens: Dave and Tom are brothers who share a bedroom. Dave is five years older than Tom. Their room is messy. Mother is angry.

2. Goal: Keep the room neat and clean.

3. Resources and Restrictions: These are not clearly specified. A few ideas occur to Dave.

   A. I have good organizational skills. I could organize the job so it is easier to do. I could break the job into some parts to be done each day and some parts to be done each week.

   B. I am a fast worker. I could do all the work myself. But that doesn't really seem fair. I think Tom should help, and so does mother.

   C. I have a habit of throwing my dirty clothes on the floor. Tom and I have a clothes hamper. But right now my model airplane is sitting on it.

   D. My younger brother really likes and trusts me. He likes to do things with me. I bet I could get him to help if we worked together.

   E. I am good at building things, and so is my mom. We could build some more shelves. That might help.

4. Ownership—importance to Dave: Dave has respect for his mother and is concerned that she is angry. He realizes that he has been setting a bad example for his brother. Thus, he has a reasonable level of interest in resolving the problem situation.

2. Devise a plan of action.

Dave thinks about the situation. Various plans come to mind. He thinks about getting more shelves. But he realizes that he already has plenty of storage space.

Finally Dave decides, "I think the best approach is to divide up the task and to make a wall chart. I'll list all of the jobs that need to be done. Tom and I will take turns picking the ones we will do. Because Tom is younger than I am, I'll let him have the first choice."

3. Carry out the plan.

Dave approaches his younger brother and explains the situation. He and Tom make a list of the jobs that need to be done each day. They make a list of the jobs that only need to be done once a week. They make a wall chart for checking off the jobs. They agree who is to do each of the jobs. They agree that they will work together on Saturday morning to get ready for mother's inspection.

4. Check to see if the problem is solved and if new problems have been created.

A week goes by. Every day Dave and Tom each do some work on the room. On Saturday morning they work together to get the room ready for mother's inspection.

The room is neater and cleaner. Dave and Tom's mother is happy with the progress. But she sees some other things that need to be done. She suggests that the wall chart needs several additions. Good progress has occurred. The problem is nearly solved!

Or is it solved? What can go wrong? Suppose that Tom stops doing his share of the work or does a poor job? After all, Tom is quite young. Maybe it isn't fair that Tom has to do half of the work.

Suppose Dave wants to be out with his friends on Saturday morning when a lot of the work is usually done? Discuss some of these questions in your journal.

Begin ✍✍ (Please write in your journal.)

1. Make a title for this journal entry. Your title might look like this:

THE PROBLEM OF A MESSY ROOM

2. Discuss possible answers to the question of what might go wrong. Then suggest ways to handle these situations.

3. Think of an entirely different plan of action Dave might try. For example, Dave might agree to do all of the work one week, and Tom would do all of the work the next week.

4. Get together with a classmate and share your ideas on a new plan of action Dave might take.

End ✍✍

More Details on the Four-Step Plan

The four-step plan is quite general. It may help you to get started in working to solve personal problems and school problems.

Please remember, the plan is just a way to get started. You don't have to follow it if it doesn't seem to be helping. Also, it is okay to skip around in using the plan. For example, suppose you think you understand your problem and you begin to develop a plan of action. But in thinking about the plan, you realize that you don't really understand the problem. Then the thing to do is to go back to the first step again.

Or perhaps you develop a plan of action and start to carry out your plan. But you realize that that isn't doing any good. Your plan of action will not solve the problem. Maybe you need to rethink your problem. In that case, you start over again at Step 1. Perhaps you need to develop a different plan. Then you will need to go back to Step 2.

Here are some more ideas about the four-step plan for attacking a problem.

1. **Understand the problem:** This is a feeling-and-thinking step. Ownership is very personal. Often you begin with a problem situation.

You work on the problem situation to pose one or more clearly defined problems. You can do this using ideas from Chapter 3. The goal in this step is to pose one clearly defined problem that you will attempt to solve.

2. **Devise a plan of action**: This is a thinking step. In getting a clearly defined problem, you identified resources and restrictions. Now you begin to think about how to use the resources and how to avoid violating the restrictions. You mentally develop a plan of action of what you will do to solve the problem. Perhaps you write down your plan of action.

3. **Carry out the plan of action**: This is an action step. Notice the clear distinction between thinking about the plan of action (deciding what to do) and actually carrying out the plan of action. In Step 2 you can imagine carrying out the plan. Perhaps you can see yourself carrying it out in your mind's eye. In Step 3 you actually carry out the plan of action.

   This distinction is quite important. Computers are very good at carrying out some plans of action. (Remember, a computer program is a detailed, step-by-step plan of action. It is designed to be carried out by a computer.) It is people who devise the plans of action that computers carry out.

4. **Examine and think about the results of your work**. This is a thinking step and a values step, drawing on everything you know. It has two parts:

   A. **Check to see if the problem is solved**. Has the goal been achieved? If yes, then you are done. But suppose not. This can happen if your plan is flawed. (Then you will need to return to Step 2.) It can also happen if you make a mistake in carrying out your plan. (Then you will need to return to Step 3.)

   B. **Check to see if new problems have been created**. The steps you take to solve one problem may create other problems. For example, suppose you have saved up some money to buy some clothes you really need. But you are bored. You decide to take a friend to a movie. You have solved your boredom problem. But now you have the problem of not having money to buy the clothes you need.

Begin ✍✍ (You may want to write in your journal.)

People often seem to forget that the process of solving a problem may create a new problem. Think of several examples where the steps you took to solve a problem created new problems. Did you create new problems that were even tougher than the original problem?

End ✍✍

Don't Reinvent the Wheel

The four-step plan can help you get started on many different kinds of problems. But all by itself, it often does not help much.

For example, suppose your science teacher gives you a hard problem from a class you plan to take next year. The problem uses words and symbols you have never seen before. You cannot even begin to understand the problem. You have no idea of the givens or the goal. You lack the resources (the knowledge of science) needed to solve the problem.

This same situation exists in every other school subject. People have been working for hundreds of years to learn to solve problems in art, language arts, math, music, science, and social studies. They have made a great deal of progress. Some researchers spend years and years working on the details of a single problem. Suppose you encounter one of these really hard problems. What should you do?

Begin ✍✍ (You may want to write in your journal.)

You have heard the expression "Don't reinvent the wheel." What do you think this has to do with problem solving? What does it have to do with solving really hard problems that other people have already solved?

End ✍✍

Build on Your Own Previous Work and That of Others

Suppose you encounter a problem you have solved before. You were happy with the results. Then probably the way to solve the current problem

is to just do what you did before. It is helpful to have a good memory. You learn from your successes and your failures.

Now think about the successes and failures of other people. Thomas Edison worked for years to develop a good light bulb. He had many many failures, but eventually he succeeded. Most people don't care about all his failures. Instead, they use light bulbs that resulted from his successful ideas.

This is a key idea. Suppose you encounter a problem that someone else has solved before. If someone has already figured out how to solve a problem, why not just use that person's method? Learn to build on the work of others.

Here is a summary of the ideas in this section. These are some of the most important ideas in this book.

1. When you encounter a problem situation, think about whether you have encountered it before. If it is a situation you have encountered before, what did you do previously? Did it work well for you? If so, most likely you will want to do the same thing again. If it didn't work well for you, most likely you will want to try something different. You may want to set a different goal. You may want to identify some additional resources or better understand the restrictions. You may want to try a different plan of action.

2. Suppose you encounter a problem situation that is new to you. First work to get a clearly defined problem from it. Then think about the possible value of finding out what other people have done when they were faced by that clearly defined problem. You might find out by talking to other people or you might find out by looking it up in a book.

This suggests two very good ways to get better at solving problems. First, solve lots of different problems and remember how you solve the problems. Remember your successes and your failures. Experience is an excellent teacher. You get better with practice.

Second, learn to build on the work of other people. There are many ways to build on the work of other people. For example:

- Learn to talk to people, to get their help in solving problems. Learn to work with groups of people.

- Learn to make use of reference books. A library is full of information about how to solve specific problems.

- Learn the subjects taught in school. Each school subject is designed to help you learn things that other people have already learned. Each school subject helps you to learn to solve certain types of problems.

Begin ✍✍ (You may want to write in your journal.)

There are many ways to build on the work of other people. Several of them are listed above. Add to the list. Then decide which ways are best for you. For example, are you better at talking to other people or using a library?

End ✍✍

The Basics of Education

School helps you learn to build on the work of other people. You have heard about "the three Rs." Reading, 'riting, and 'rithmetic are some of the basics of education. They are called basics because they are useful in so many different ways. They are especially useful when you want to build on the work of other people.

Reading provides a good example. Because you know how to read, you can look up information in a library. You can read about the work other people have done. You can make use of this as you work to solve your own problems.

There are a number of "basics" of education. Each is important in understanding and solving a wide range of problems. However, perhaps some of the basics of education are more important to you than others. Think about that as you do the following journal-writing activity.

Begin ✍✍ (Please write in your journal.)

A whole lot of school is devoted to helping you get better at some of the basics, such as reading, writing, arithmetic, speaking, and listening. Please do the following journal-writing activity.

1. Make a title for this journal entry. Your title might look like this:

   _____

   USING THE BASICS OF EDUCATION TO SOLVE PROBLEMS

2. Give a clearly defined problem you have solved in which you made use of your ability to read.

3. Give a clearly defined problem you have solved in which you made use of your ability to write.

4. Give a clearly defined problem you have solved in which you made use of your ability to do arithmetic.

5. Give a clearly defined problem you have solved in which you made use of your ability to speak.

6. Give a clearly defined problem you have solved in which you made use of your ability to listen.

End ✍✍

School Subjects

Many school subjects have a narrow focus. In a writing class you learn to do writing, and in a math class you learn to do math. Do you think it would be okay to spend some math class time doing writing about math? Can you think of how you might use math in a writing class? A more general question is, do the ideas that you learn in one class apply to other classes?

Here is an example that helps explain the above ideas. A science class focuses on what people know about science. It helps you to understand the types of problems scientists know how to solve. It helps you to understand the types of problems scientists are currently working on. One major goal in a science class is to help you learn to think like a scientist. Learn to attack problems the way a scientist does.

Scientists use the "scientific method." They develop theories that describe what is happening. Then they work to test their theories. For example, Albert Einstein developed a theory about moving objects. His theory helped explain what happens when an object moves very fast. He and a number of other scientists worked to design tests of his theory. Einstein's theory is quite famous. It is called the theory of relativity.

Is the scientific method useful in courses outside of science? For example, do historians develop theories and test their theories?

The types of problems one studies in each subject are different. But often there is an overlap between courses. The types of problems one learns about in a health class are different from the types of problems one learns about in a history class. But in a health class you might learn some of the history of medicine. In a history class you might learn about some of the health problems people had a long time ago. In both classes you might use ideas from math to draw a bar graph of important data. The methods used to solve problems in one subject may be the same as the methods used in another subject.

It is very helpful to know a little bit about every school subject. This will help you to understand the kinds of problems the subject deals with. Even just a little bit of knowledge can be the starting point for solving a problem that deals with a subject area. Moreover, the ideas you learn about in one subject may help you solve problems in an entirely different field.

CHAPTER 4 SUMMARY

Many problems can be solved by following a four-step plan:

1. Understand the problem.
2. Devise a plan of action.
3. Carry out the plan of action.
4. Check the results.

In devising a plan of action, it is very helpful to build on the things you already know and the things other people know. School helps you to learn the things others have already discovered about solving problems. Each school subject focuses on understanding and solving problems in one particular field.

Activities

1. Pick some idea you thought about while reading this chapter. Perhaps you thought about how you build on your experiences. Perhaps you thought about why some school subjects are more fun for you than other school subjects. Write several paragraphs in your journal about some idea you thought about. You might want to use the outline given below.

    1. Make a title for this journal entry. Your title might look like this:

    _____

    CHAPTER 4 ACTIVITY 1
    AN IDEA I HAD WHILE I WAS READING CHAPTER 4

    2. Write down and explain the idea.

    3. Explain why the idea interests you. Why did you remember this idea?

    4. How does this idea relate to things that you do outside of this class?

    5. What else do you think about when you think about this idea?

2. Get together with two or three other students in the class. Each of you is to select one idea from this chapter that seems particularly important to you. Each of you is to spend a minute or two talking about the topic. Why did you select it? Why is it important to you? What difference does it make in your life?

    In talking about your topic, try to make use of some of the new terms introduced in this chapter as well as terms from the earlier parts of this book. A list of new terms is given below. Remember, definitions are given in the Glossary.

    four-step plan for solving a problem
    unsolvable problem

3. Make up a short quiz of lower-order thinking skill questions for this chapter. (Include correct answers. Often a lower-order skill question has only one correct answer.) Your quiz should consist of questions that can be answered by a person who has a low level of knowledge of the material in this chapter.

    Then try out your quiz on two students in your class.

4. Make up a short quiz of higher-order thinking skill questions for this chapter. (Think about some possible correct answers. Remember that a good higher-order skill question is likely to have many different correct answers.) Your quiz should consist of questions that can be answered by a person who has a good understanding of the material and ideas in this chapter.

   Then try out your quiz on two students in your class.

5. Each class you take focuses on a particular type of problem. The main goal of a math class is to help you understand and learn to solve math problems. The more you know about math, the better you will be at solving math problems. Please do the following journal-writing activity. You may want to get some help from your math teacher. Use a title line such as:

   CHAPTER 4 ACTIVITY 5
   SOLVING PROBLEMS USING MATH

   1. What is math? Write a brief definition that you feel adequately defines the field. Your definition should be understandable by other students in your class.

   2. What are some of the types of problems people learn to solve by studying math?

   3. Give some examples of problems in nonmath subjects that math can help solve. To do this, think of each subject you are taking. For each one, give an example of where math can be used.

   4. Give two different examples of problems that occur outside of school where math is useful.

6. Do the previous exercise for some other subject area you are studying.

7. Many years ago people were faced with a transportation problem. They invented the automobile to help solve this problem. Give several examples of problems that this "solution" has created.

8. Brainstorm on the following questions:

   A. What problems does television help solve? For example, does television help to solve some particular communication problem?

B. What problems does television help create? For example, does watching a lot of television use up time that could better be used for other purposes?

9. Brainstorm on the following questions:

   A. What problems does school help solve? Include specific examples from your life.

   B. What problems does school help create? Include specific examples from your life.

10. One way to tell if you have solved a problem correctly is to ask the teacher. Brainstorm a list of other ways to tell if you have solved a problem correctly. Then get together with two other students in the class and share your lists. Do some more brainstorming in your group. *It is very important to understand that once you get out of school there will not be an "answer book" or a teacher to tell you if your answers are correct.*

Chapter 5
Problem-Solving Strategies

ORGANIZE YOUR THINKING

A strategy is a general plan of action for attacking a problem. Some strategies are only useful in a specific subject area or type of problem. A strategy for solving science problems might not be useful in solving sports problems. Other strategies are useful for a wide range of problems.

You can get better at problem solving:

- By learning to use strategies designed to fit problems in one subject, such as math or business.
- By learning to use a number of strategies designed to be useful in many different problem areas.
- By learning about the roles of computers in making use of strategies.

Introduction

Chapter 4 contains a four-step plan that can be used to attack a wide range of problems. It does not solve any specific problem for you. But quite often it will tell you how to get started. That is very important. If you can get started on a problem, you have a chance to solve the problem.

The four-step plan is an example of a problem-solving strategy. A strategy is a plan of action. It tells you some things to do or think about that might help solve a problem. By learning to use the four-step strategy, you can get better at solving problems.

There are many strategies for problem solving. Some are useful for a wide range of problems. For example, consider a strategy for dealing with people. A useful strategy is, "Be a good listener. Be interested in what others have to say." This strategy is useful in dealing with all people you meet.

Other strategies are quite specific and are useful for just a narrow range of problems. For example, here is a strategy that many students use in a math class: "When you have to do a problem from the book, page back into the chapter until you find a worked-out example. Do the same thing that was done in that example." Often this strategy will help you solve the book problem.

However, this is not a very good strategy. First, lots of times it will not help you solve the book problem. But more important, it is a poor strategy for learning math. The purpose of math homework is to help you learn math—not just "get the answers." It is necessary to understand the problem and to think carefully about what you are doing if you are going to learn math.

Strategies for Getting Better at Solving Problems

Your mind is good at learning strategies. When you solve a problem, your mind remembers the general ideas of what you are doing. Suppose that some time later you encounter a somewhat similar problem. Your mind may recognize the new problem as somewhat similar to one you have solved before. It will suggest that you use the same approach you used before. That is, your mind tends to use the strategy, "Do what worked before."

However, there are lots of different strategies. Sometimes your mind will develop a strategy that doesn't work very well. You will use the strategy over and over again, even though it isn't very useful. Can you think of an example of this in what you do?

This is a key idea. Your mind may be very happy trying the same thing over and over again, even when it doesn't seem to be working. It gets "stuck in a rut." It requires careful thinking to get out of such a rut. When you are working on a problem and your strategy isn't successful, don't just keep doing the same thing over and over again. Do something different! Almost anything different is better than continuing in the rut that doesn't work.

Begin ✍✍ (You may want to write in your journal.)

Think of at least two different strategies you often use but that often don't work very well. For example, you may have a certain strategy you use in dealing with a younger brother or sister. You may have a certain strategy

you use in dealing with your parents. You may have a certain strategy you use in studying for major tests.

End ✍✍

In this chapter you will learn more about strategies. You will learn some very powerful strategies that can help you to solve hard problems.

Begin ✍✍ (You may want to write in your journal.)

Suppose that your teacher is going to give a big test next week. Think of three different strategies you might use so you will do well on the test. For example, perhaps you use the strategy of "cramming" the night before the test. Which strategy seems best to you? Is this strategy best for all subjects you are taking?

End ✍✍

There Are Lots of Strategies

Researchers have found that most students know just a few general strategies for attacking problems. They use the same strategies over and over again. Sometimes the strategies work. But other times they don't work. Then the student is stuck, with no idea of what to do.

You can get a lot better at problem solving by learning additional general strategies. It is easy to memorize some new strategies. But it is much harder to learn when and how to use the strategies. This requires practice.

Suppose you are working with a problem situation where there is no clear goal. Here are some strategies for getting a list of possible goals:

1. Brainstorm all by yourself.

2. Brainstorm in a group or with a friend.

3. Ask your teacher for some possible goals.

4. Read a book on the topic. Find goals suggested by the author.

5. Examine your feelings very carefully. Why do you have some ownership in this problem situation? What would make you feel better about the situation? Think of goals that will make you feel better.

Each of these is a general strategy. Each may be very useful for some situations and not useful for other situations. For example, if you are taking a test, you can use the first strategy. Unless it is an open-book test, you are not allowed to use the fourth strategy.

When you are solving a problem, one of the resources is your time. Usually you will be able to think of several different strategies to use on a problem. But you may not have enough time to apply every possible strategy you can think of. You want to apply a good strategy—one that will work well. How can you tell which strategy to try first?

There is no easy answer to this. However, training and experience can help. To a large extent, you have to teach yourself. The way to do this is by metacognition. As you solve problems, think about what you are doing. Think about the strategies you are using. Think about other strategies you have decided not to use. This type of metacognition will help you become much better at solving problems.

Begin ✍✍ (Please write in your journal.)

In this activity you will need to work alone for a while. Then you will want to share your results with a group of students in your class.

You spend a lot of time in school memorizing facts. You memorize how to spell words. You memorize important names and dates. You memorize formulas in math and science.

1. Make a title for this journal entry. Your title might look like this:

STRATIGIES I USE TO HELP ME MEMORIZE THINGS

2. Make a numbered list of at least three different strategies that you use to help you memorize things.

3. Discuss which one or two are best for you, and why.

Now get together with two or three other students. Share your strategies. Talk about what works best for each of you. When you learn some good ideas, write about them in your journal. Have any of you read a book on how to get better at memorizing?

End ✍✍

The Top-Down Strategy

There are many general purpose strategies that may help you solve a problem. For example, consider the following strategy, which was mentioned in Chapter 1.

> Break big problems into smaller problems. (The smaller problems may be much easier to solve.)

This is such an important strategy that it has a name. It is called the **top-down strategy**. The idea is to start at the "top" of a problem—with the big picture. Break the problem "down" into smaller pieces.

The top-down strategy is so useful and so easy to use that you do it all of the time. Probably you don't even think about it. For example, you wake up in the morning and it is a school day. You have the problem of getting to school. You break it into smaller problems:

1. Getting dressed, combing hair, brushing teeth, and so on.
2. Getting breakfast.
3. Getting the stuff ready that you need to take to school.
4. Getting to the bus stop in time to catch the school bus.

For another example, suppose that your teacher assigns a big term paper. You might break this task into some smaller tasks.

1. Decide on a topic.
2. Find a number of sources of information about the topic.
3. Read the information and keep good notes.

4. Write the paper.

In each of these two examples, a big problem is solved by solving a number of smaller problems.

Begin ✍✍ (You may want to write in your journal.)

Sometimes when you break a big problem into smaller problems it is clear that the smaller problems must be solved in a certain order. In other cases the order does not make any difference. It may be best to work on one of the subproblems for a while, and then switch to another. Think about the examples of getting to school and doing a term paper given above. Does the order in which you do the smaller problems make any difference?

Make up an example in which the order of doing the subproblems is very important. For example, suppose you are planting some flowers in a garden. You are going to dig a hole, put a plant in, and fill the dirt in. What happens if you do these steps in a different order?

End ✍✍

The Bottom-up Strategy

There is another general purpose strategy that you also use quite often. Probably you have watched a small child play with building blocks. There does not seem to be any plan in what the child is doing. The child puts several of the blocks together. The child is pleased with the result and adds more blocks.

The **bottom-up strategy** begins with "building-block" problems. These are problems you know how to solve and tasks you know how to do. You put some of them together. As you see what results, perhaps you are led to add more parts. Perhaps you are led to setting a goal. This is a very creative process. Many artists work this way.

The bottom-up strategy is used in two different ways. Sometimes it is used with no goal in mind. The initial activity may seem rather random, like a child playing with building blocks. A goal is created that fits with the progress that has occurred. For example, you begin to doodle. You draw several different shapes. Then you see that one of the shapes looks like the

tail of a cat. Another of the shapes looks like a tree branch. You decide to draw a picture of a cat in a tree.

At other times the bottom-up strategy is goal directed. For example, it is after school and you are hungry. Your goal is to get something to eat. You go to the kitchen to get a snack. You open the refrigerator and see some sandwich makings. You look in the bread drawer and see a loaf of bread. You decide that you would like a sandwich. You have used a bottom-up strategy to decide on the goal of making a sandwich.

Begin ✍✍ (You may want to write in your journal.)

Think of two different times that you have used the bottom-up strategy. First think of a time that you were goal directed. Then think of a time you used the bottom-up strategy and were not goal directed.

Which of the two examples seemed easiest for you to think of? Why?

End ✍✍

Primitives: Building-Block Problems

In using the top-down strategy, the goal is to break the original problem into smaller problems you know how to solve. In using the bottom-up strategy, the starting point is smaller problems you know how to solve.

In both cases, you need to have a set of building blocks—problems you know how to solve or tasks you know how to do. These are called **primitives**. A primitive is a problem you know you can solve. Usually it is a problem you can solve quickly and easily. It is a resource that is available to you when you begin to attack a problem.

For example, do you know the "times" table? Can you quickly and easily give the answer to simple problems, such as 8 x 9, 3 x 7, and 6 x 8? If so, you have a set of primitives that are very useful in many different situations. These multiplication-fact primitives are useful in doing larger multiplication problems. They are useful in doing paper-and-pencil long division. They are useful in doing mental estimations on arithmetic problems.

This book uses the word "primitive" for a basic building-block problem or task. Every field of study has primitives. In a sport such as volleyball, for example, it is necessary to learn the basic moves or the fundamentals. The basic moves and the fundamentals are primitives for a person who is good in that sport.

Begin ✍✍ (You may want to write in your journal.)

Think of some field you know well. Maybe you are good at ballet. Maybe you are good at wood working. Make a list of primitives for the field you select. Remember, these are building-block problems you can easily solve.

End ✍✍

A Calculator Primitive

One way to get better at problem solving is to learn more primitives. That is what you do when you take a course in school. A course teaches you some of the primitives that are useful in solving the problems in the field the course covers. In a science course you learn primitives that are useful in attacking a variety of science problems. In an art course you learn primitives that are useful in working on a variety of art problems.

But it takes a lot of time and effort to learn new primitives. People are always searching for ways to avoid this work. One way is to build a machine that can solve certain kinds of problems. A hand-held calculator is a good example of such a machine. Even an inexpensive calculator can add, subtract, multiply, and divide. That is, it can carry out the process needed to solve four different types of problems. It provides you with four different **calculator primitives**.

A hand-held calculator is a limited-purpose computer. It contains the same type of circuitry, although usually there is not as much of the circuitry. There is no clear dividing line between a calculator and a computer. An expensive calculator has many computer-like features. Some of the least expensive computers are not as powerful as some of the more expensive calculators.

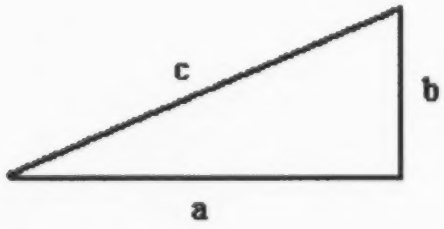
Most hand-held calculators have a key that is labeled √. This is the square root key. Suppose that you enter the number 144 into the calculator and then push the √ key. The calculator will find the square root of 144 for you. It will quickly display the number 12. The square root of 144 is 12, because 12 x 12 = 144.

(Note: This is not a math book. Students of mathematics know that a positive number has two square roots. Both +12 and -12 are square roots of 144. But we will just talk about "the" square root of a number. We will mean the positive square root.)

The problem of finding the square root of a number occurs quite often in engineering, science, and math. It is a very important primitive. There are two aspects of this primitive. First, what does "square root" mean? That is, what is the concept of square root? Second, how do you calculate the square root of a number? What process does one use to find a square root?

It is easy and fun to learn the concept of square root. You can easily see that 4 x 4 = 16, so 4 is the square root of 16. You can easily see that 1.3 x 1.3 = 1.69, so 1.3 is the square root of 1.69. Note that 1/2 x 1/2 = 1/4. In this case, the square root of a number is actually bigger than that number!

In addition, you can experience the joy of the Pythagorean theorem. It is an important application of square root. Take a look at the right triangle below. (A right triangle has a 90-degree angle in it.)



The sides of the triangle have lengths a, b, and c. The angle between the sides of length a and length b is 90 degrees. The Pythagorean theorem tells how to find the value of c when you know the values of a and b. The way to do this is to calculate the value of $a^2 + b^2$. Then calculate the square root of this number. For example, suppose that a = 4 and b = 3. Then c is the square root of 25.

The Pythagorean theorem illustrates a very important idea in problem solving. It is the idea of building on the work of others. The theorem was first discovered and proved more than 2,000 years ago. Since that time, many millions of people have built on this important piece of work done by Pythagoras.

As you can see, the concept of square root is not too hard to learn. It is much harder to learn to calculate the square root of a number. It used to be that schools taught students to calculate square roots using pencil-and-paper methods. Students were required to memorize how to do this. The procedure they learned is much more complicated than long division. Most students take a long time to memorize this procedure. They soon forget it unless they use it regularly.

Now most schools have dropped this topic from their high school math classes. Students are taught the concept of square root. They are taught how to use a calculator to find the square root of a number. Thus, students have square root as a calculator primitive in solving engineering, science, and math problems. They still learn the concept of square root. But they save a lot of study and practice time. It is much easier to learn to use a calculator than it is to learn a pencil-and-paper method to calculate square roots.

Begin ✍✍ (You may want to write in your journal.)

The square root example has two parts. First, it involves the *concept* of the square root problem. Second, it involves the *process* of how one actually solves a square root problem. All problems can be divided into these two parts—concept and process.

Think of some problems you know how to solve. For each, separate the concept from the process. To do this, describe the concept without describing the process. For example, think about looking up a word in a dictionary or looking up a topic in the library. In each case the concept and the process are two different things.

End ✍✍

Computer Primitives

A computer program is a detailed, step-by-step set of directions. It is a plan that tells a computer what to do. A computer program may be a plan telling a computer how to solve a particular type of problem. It may be a plan telling a computer how to accomplish a particular task.

Suppose you have access to a computer and a large collection of computer programs. You can think of each of these computer programs as a **computer primitive**. Each computer program can quickly and easily solve a problem or do a task for you. The computer gives you a very large number of primitives.

But remember, a problem (a primitive) has both a concept and a process. The computer can quickly and accurately carry out the process. But this is of no use to you unless *you* understand the concept.

This may be the single most important idea about computers. A computer can help you to gain a very large number of primitives. There are many thousands of computer programs that solve problems. Each problem has underlying concepts. A computer can carry out the process of solving these problems. If you learn the concepts underlying these problems, you will have gained the problems as primitives.

Begin ✍✍ (You may want to write in your journal.)

You have seen posters and drawings done by a graphic artist. The lettering in these products is done very precisely and neatly. A graphic artist is skilled in doing the designs for the posters and drawings. A graphic artist may also be skilled in actually doing the lettering and drawing by hand. But often a computer can do the lettering. It is easy to learn to use a computer to do neat and very precise lettering. It is much harder to learn the concepts of designing a poster or drawing.

Give several examples of processes that you know a computer can do. Give the concepts that a person would need to learn in order to make good use of these computer processes.

End ✍✍

CHAPTER 5 SUMMARY

Strategies are plans of action. They are general ways to attempt to attack a problem. Some strategies are very specialized. Other strategies can be used on a wide variety of problems. The top-down and the bottom-up strategies are very useful for many different problems.

Primitives are problems that you can solve easily and accurately. You can make use of primitives in the top-down strategy and in the bottom-up strategy.

A primitive consists of both a concept of a problem and a process for solving the problem. A computer can carry out the process needed to solve many problems. If you learn the concepts underlying these problems, you will have gained them as primitives.

Activities

1. Pick some idea you thought about while reading this chapter. Perhaps you thought about some problem-solving strategies you use all of the time. Perhaps you thought about some strategies not mentioned in this chapter. Perhaps you thought about the fact that you spend a lot of time learning to do things computers can do for you. Write several paragraphs in your journal about some idea you thought about. You might want to use the outline given below.

    1. Make a title for this journal entry. Your title might look like this:

    CHAPTER 5 ACTIVITY 1
    AN IDEA I HAD WHILE I WAS READING CHAPTER 5

    2. Write down and explain the idea.

    3. Explain why the idea interests you. Why did you remember this idea?

    4. How does this idea relate to things you do outside of this class?

    5. What else do you think about when you think about this idea?

2. Get together with two or three other students in the class. Each of you is to select one idea from this chapter that seems particularly important to you. Each of you is to spend a minute or two talking about the topic. Why did you select it? Why is it important to you? What difference does it make in your life?

   In talking about your topic, try to make use of some of the new terms introduced in this chapter as well as terms from the earlier parts of the book. A list of new terms is given below. Remember, definitions are given in the Glossary.

   bottom-up strategy
   calculator primitive
   computer primitive
   primitive
   top-down strategy

3. Make up a short quiz of lower-order thinking skill questions for this chapter. (Include correct answers. Often a lower-order skill question has only one correct answer.) Your quiz should consist of questions that can be answered by a person who has a low level of knowledge of the material in this chapter.

   Then try out your quiz on two students in your class.

4. Make up a short quiz of higher-order thinking skill questions for this chapter. (Think about some possible correct answers. Remember that a good higher-order skill question is likely to have many different correct answers.) Your quiz should consist of questions that can be answered by a person who has a good understanding of the material and ideas in this chapter.

   Then try out your quiz on two students in your class.

5. Think of a strategy you use when you have a problem with a friend. You most likely have used this strategy in dealing with other people. Give an example of how this strategy can be used with people who are not your friends.

6. Pick one of the courses you are taking. Make a list of some of the primitives you are learning in that course.

Now pick a different course you are taking. Make a list of some of the primitives you are learning in that course.

Which course seems to have the most primitives? Why do you think one course teaches more primitives than the other?

7. For this activity, use the same courses you used in Activity 6. Look at the two lists of primitives. For each primitive, think about a process for solving the primitive. Which of these processes do you think a computer could do?

   Does one of the courses seem to have more computer primitives than the other? Why do you think this is the case?

8. A primitive consists of both a concept and a process. Some people are better at learning concepts. Other people are better at learning processes. Which are you better at? Why?

   In answering this question, think about the examples from Activity 6.

9. There are many different ways to solve most problems. For some primitives, you will want to know how to do the process by hand and by computer. The problem of checking your spelling is a good example. Sometimes you need to check by hand. Other times a computer is very helpful.

   Give other examples of where it is very useful to know both a by-hand and a by-computer method for solving a primitive.

10. Make a list of strategies you use to cope with the assignments and tests in:

    A. The course you do best in.

    B. The course you do worst in.

    Compare and contrast the strategies. Do you use the same strategies in both courses? Draw conclusions if possible.

Chapter 6
Getting Better at Thinking

ORGANIZE YOUR THINKING

This chapter discusses a number of things you can do to get better at thinking. As you get better at thinking, you will get better at solving problems. To get better at thinking:

- Learn what more effective thinkers do.
- Understand your own more effective thinking-skill habits and your less effective thinking-skill habits.
- Develop more effective thinking-skill habits and practice them.

Introduction

Here are three things related to getting better at solving problems that schools can help you to do:

1. Learn basic information and basic skills.
2. Learn to solve specific problems that occur frequently and that are considered to be quite important. (Increase your storehouse of primitives.)
3. Learn general purpose problem-solving and thinking skills that can be used with any problem you encounter.

Begin ✍✍ (You may want to write in your journal.)

Think about the three ways listed above of spending school time. One approach would be to spend about one-third of the time in each category. What do you think about that? If you were in charge of schools, how would

you divide up the time? Do you think that the division of time should be the same for every student?

End ✍✍

It seems clear that schools should spend quite a bit of time helping students gain general purpose problem-solving skills. The task is to help prepare you to deal with the unexpected. You need to learn to solve problems that you have not seen before.

One way schools can help you do this is to help you become a more effective thinker. You have a very good mind. With training and experience, you can get more and more effective at using your mind. This chapter will give you some help in becoming a more effective thinker.

What Is Thinking?

The word "think" has a number of meanings. Each person has good ideas on what the word means. Please do the following journal-writing exercise.

Begin ✍✍ (Please write in your journal.)

1. Make a title for this journal entry. Your title might look like this:

   WHAT DOES THE WORD "THINK" MEAN?

2. First work by yourself. Brainstorm a large number of ideas of what "think" and "thinking" mean to you.

3. Get together with two other students in your class and share your ideas.

4. Then write a good definition in your journal.

End ✍✍

Now reread the definition you wrote in your journal. Does your definition indicate that people can get better at thinking? Does your definition suggest that different people think in different ways?

Do some metacognition. When you think, do you make pictures in your head? When you think, do you talk to yourself inside your head? When you think, do you have hunches or use your intuition? When you think, do you sense your feelings?

Begin ✍✍ (You may want to write in your journal:)

There are many ways to think. Some people are better at thinking in pictures. Others are better at thinking in words. Both are very useful. Which are you better at? How do you know this?

Try the following experiment. Your goal is to think of two different problems you have solved today. The first problem should be one where you used pictures in your head as an aid to thinking. The second should be a problem where you used words in your head as an aid to thinking.

Now, do some metacognition on the task you just completed. Did you use pictures in your head or words in your head as you carried out the experiment?

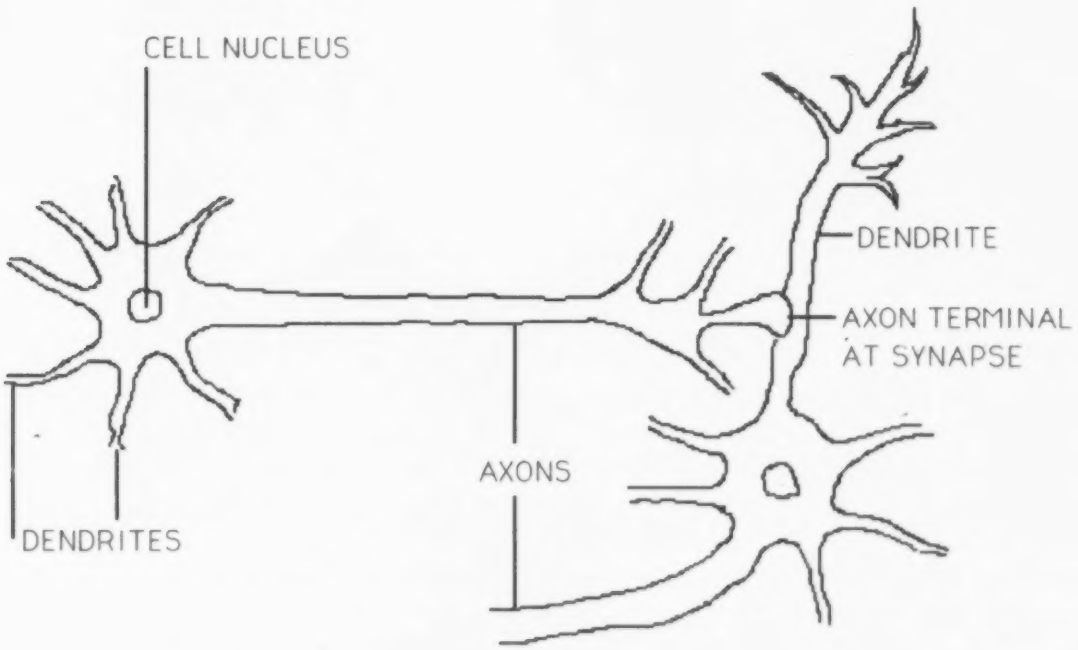
End ✍✍

Brain Theory

The human brain is very complex. Brain researchers have been making a lot of progress in recent years. But the brain is so complex that they still have a lot to learn. Researchers are just beginning to understand how the brain learns and what helps it to learn. They are just beginning to understand what the brain does when it is thinking. They are just beginning to understand what happens to the brain when it gets a disease such as Alzheimer's.

One of the basic building blocks in the brain is the neuron. The neurons store and process information. A typical human brain has between 30 billion and 100 billion neurons. A neuron is so small that 30,000 of them will fit into a space the size of a pin head! The neurons store information and they

also process information. The following picture shows two neurons. A single neuron may have connections to thousands of other neurons. When you are thinking about a problem, tiny electrical currents flow through these connections, passing messages among the neurons.



In recent years, scientists have developed ways to "see" the brain in action. They can actually take pictures that show which parts of the brain are active when it is doing various tasks. Several key ideas have emerged:

1. Most brain activity occurs at a subconscious level. When we talk and think about a problem, billions of neurons may be involved. We do not consciously control all of this neuron activity.

2. Good thinkers make more efficient use of their brains than do poor thinkers. That is, when a good thinker is solving a problem there is less brain activity than when a poor thinker is working on the same problem. Training and practice make the brain more efficient. There is a good analogy with the economy of motion of a trained athlete. The trained athlete has economy of motion. Energy is not wasted!

You have seen many highly trained athletes. They have learned to make very effective use of their minds and bodies in dealing with athletic tasks. They get better through hard work, continued practice, and continued study.

The same ideas hold for becoming a more efficient thinker. You have a very good brain. Through study and practice your mind will become more capable. You can become a more efficient thinker.

Persistence in Problem Solving

Educators have done a lot of research on thinking and problem solving. They have studied how people think and solve problems. They have carefully studied people who are very efficient thinkers and people who are less efficient thinkers. They have developed a number of ways to help students get better at thinking and solving problems.

You know that many problem situations are very complex. They do not have easy solutions. It is easy to make mistakes when dealing with hard problems. Solving hard problems can take a lot of time and effort. Some people are much more persistent than others.

Researchers have found that the more effective thinker is willing to work long and hard on a problem. Thomas Edison was a very hard worker. He once indicated that his success as an inventor was based on "98% perspiration and 2% inspiration." A good example is provided by his work in inventing the electric light bulb. The problem was to develop a filament that would give good light and not burn out very fast. Edison tried hundreds of different materials. It was only through great persistence that he finally came up with a good, useful light bulb.

Researchers have found that people who are poor at solving problems often lack persistence. When they have a problem, they try one or two different things. If they don't quickly succeed, they give up.

Of course, blind and unthinking persistence is not useful. If one approach is not working, try a different approach! Don't just keep doing the same thing over and over if it is not working. Learn to recognize when the approach you are using isn't working.

Begin ✍✍ (You may want to write in your journal.)

Think about your persistence in solving problems. Do you give up easily, or do you keep trying? How would you compare your persistence with that of your friends?

Give an example where you kept trying and eventually solved a hard problem. Give an example where (maybe) you gave up too soon.

Probably you are more persistent on some problems than on others. Can you tell in advance of starting a problem how persistent you will be? What kinds of problems are you apt to be most persistent on?

End ✍✍

The metacognition you have just done is very important. You can look at your own habits. When you have a problem, do you keep working until you solve it? Or do you give up easily? Persistence is very important. You will get better at problem solving if you learn to "keep trying."

In the rest of this chapter we will discuss a number of other "more efficient" thinking and problem-solving habits. You may find that you have many quite efficient thinking-skill habits. But you may also find that some of your thinking-skill habits are not as efficient as they could be. This is very valuable information. It can provide a starting point for improving your ability to think and solve problems.

It is not easy to change your thinking-skill habits. After all, you have been practicing these habits all your life. They have served you quite well. But you can get a lot better at thinking. This takes study and practice. At first you need to carefully and consciously think about your thinking patterns. Slowly, with lots of practice, you will develop new habits. Eventually you will use your new thinking habits without conscious thought. You will have become better at thinking.

Some General Considerations

1. Dealing With a Lack of Clarity

Suppose you run into a problem situation that concerns you. At first the situation is probably not clear. Remember, there are many possible goals. There are many possible resources and restrictions that might relate to any particular goal. What do you do?

More efficient thinkers enjoy finding problem situations that are not clearly defined. They enjoy developing clearly defined problems. They can make up many different problems from a problem situation.

Less efficient thinkers search for certainty and have difficulty dealing with unclear problem situations. They would rather ignore a problem situation than do the thinking required to deal with it. They are satisfied in making up just one problem from a problem situation.

2. Seeing Others' Points of View

Most problem situations can be looked at in many different ways. The same problem situation can lead to many different goals. People have different points of view. Often there are many different ways to approach a problem or to achieve a goal.

More efficient thinkers are able to find and think about many different points of view. They can find strengths and weaknesses in different points of view. They can analyze evidence supporting different points of view. They can understand different people's points of view. They can argue both sides of an issue.

Less efficient thinkers do not consider alternatives. They have trouble understanding others' points of view. They form a first idea and hold to it. They are not open to other possibilities. They cannot think of arguments that might support a differing point of view.

3. Valuing Education and Good Thinking

Humans are naturally pretty good at solving problems. They can get better by study and practice. They can get better by learning the types of subjects taught in school. This is a key idea. Research on problem solving strongly supports the need to learn different subjects.

More efficient thinkers believe in the value of learning. The more you know, the better you can understand different kinds of problems. More efficient thinkers know that thinking can help a person to understand and solve problems.

Less efficient thinkers overvalue intuition. They may feel that school is not important. They may believe that thinking won't help them to understand and solve problems.

4. Attitude and Self-Confidence

If you believe you can do something, you probably can. Having self-confidence and a positive attitude are very important. Research suggests that these are two of the most important aspects of being good at solving problems.

More efficient thinkers have a positive attitude. They believe in the value of being a more efficient thinker. They have confidence in dealing with problem-solving situations.

Less efficient thinkers have a negative attitude. They lack self-confidence in dealing with problems.

Begin ✍✍ (You may want to write in your journal.)

Do some metacognition on the ideas discussed in the previous four sections. For each main idea, do you think of yourself as a "more efficient" thinker or as a "less efficient" thinker? Which are you best at? Which are you worst at? How can you tell? What are you doing about improving your efficiency as a thinker?

End ✍✍

Understand the Problem: Developing Goals

5. Searching for Goals

As we learned in the Chapter 3, many problem situations do not have clearly stated goals. The same problem situation can lead to many different goals. But the choice of a goal is very important. The goal directs the

problem-solving efforts. You don't have enough time and resources to solve every problem—to reach every possible goal.

More efficient thinkers can list many possible goals for a problem situation. They can examine such a list of goals and make good decisions about which goal or goals might be best.

Less efficient thinkers are not able to think of many possible goals. They often give little thought to picking a good goal to work on. They tend to have the attitude that "one goal is as good as another." Often they would prefer that someone else tell them "the" goal rather than develop goals by themselves.

6. Revising Goals

As you work to solve a problem, you gain a better understanding of the problem. Often you will find that your first understanding was not correct. You may find that the goal you have selected cannot be reached with the resources you have available, or you may find that it is a poor goal.

More efficient thinkers give careful thought to what goal they will try to achieve. If it becomes evident that they have selected a poor goal, more efficient thinkers revise their goal or select a different, better goal. They are flexible and open to change.

Less efficient thinkers continue to try to reach the initial goal, even if it is a poor goal. If the goal cannot be reached, they give up rather than select a more appropriate goal. They may have persistence, but they do not use their persistence in a wise fashion.

Begin ✍✍ (You may want to write in your journal.)

Think about the ideas discussed in Sections 5 and 6. Which of them apply to you? Which are your strengths and weaknesses? Think of examples where you exhibited the "more efficient" thinker's habits.

Think about some problem situation you have dealt with recently. How did you decide on a goal? Did you change your mind once you started working on the problem? Did you revise your goal?

End ✍✍

Understand the Problem: Resources and Restrictions

7. Resources

You can't solve a problem without using resources. But what resources do you have that are applicable? This is often the hardest question to answer when working to solve a problem. You must know your own strengths and weaknesses. You must learn the types of resources you can bring to bear on different kinds of problems.

More efficient thinkers are good at brainstorming lists of resources that might be useful in solving a problem. They are open to resource ideas suggested by others. They actively seek new resources.

Less efficient thinkers are not good at brainstorming lists of resources. They prefer to deal with limited possibilities and are not open to others' ideas of possible resources. Often they conclude that "it can't be done with the resources available" rather than seek additional resources.

8. Restrictions

Every problem-solving situation has some restrictions. Most often these are not clearly stated. Sometimes one assumes some restrictions that don't really apply.

More efficient thinkers know a number of restrictions that usually apply when dealing with problems. (For example, don't lie, cheat, or break the law.) However, more efficient thinkers know that sometimes it is appropriate or necessary to "bend" or even break the restrictions. (Is it ever okay to tell a "white lie" to avoid creating a worse problem? When is it okay to try to get around the rules?)

Less efficient thinkers may not know the restrictions that commonly apply. They may rigidly apply restrictions that are not necessary or appropriate. They may lack flexibility in dealing with rules.

Begin ✍✍ (You may want to write in your journal.)

Think about the ideas discussed Sections 7 and 8. Do they make sense to

you? Give examples of problem situations where you were a "more efficient" thinker.

End ✍✍

Evaluating Possible Different Plans

9. Finding and Using Evidence

In most problems, you have a lot of different resources and restrictions. You can think of a lot of different plans of action that use the resources and remain within the restrictions. Different people will think of different plans. You may think of several different plans. Which plan should be used?

More efficient thinkers seek evidence that challenges a proposed plan of action. What are the bad features of the plan? What might go wrong? What are possible bad outcomes? More efficient thinkers use this type of thinking to try to find a better plan of action.

Less efficient thinkers do not seek evidence that challenges a proposed plan of action. They ignore evidence that challenges a plan they have selected. They are not interested in hearing about things that might go wrong or possible bad outcomes.

10. Anticipating Outcomes

To solve a problem, you devise a plan of action and you carry out the plan. Carrying out the steps in the plan makes a change in the world. It uses some of your time and other resources. It may create new problems.

For example, suppose that you have a laundry basket of dirty clothes. Your goal is to have the clothes be clean. You decide that it will be cheapest and fastest to throw all of the clothes into one washing machine load. You don't think of the possibilities that (1) this may overload the machine so that the clothes don't get clean and/or the machine will break or that (2) your new red socks may run, and thus dye all of your white things pink.

More efficient thinkers can imagine the consequences of carrying out a course of action. They can detect side effects—new problems that might be created by a plan of action.

Less efficient thinkers do not consider possible consequences of a course of action. They often act rashly and seem surprised at unexpected outcomes.

Begin ✍✍ (You may want to write in your journal.)

Think about the ideas discussed in Sections 9 and 10. Which seem most important to you? Give examples of problems where you were a "more efficient" thinker.

End ✍✍

Is the Problem Solved?

11. Have I Solved the Problem?

It often happens that you carry out a plan of action, but the problem is not solved. The plan of action may be a poor plan, or you may make errors in carrying out the plan. How can you tell if the problem has been solved?

When thinking about goals, the more efficient thinker asks, "How can I tell if I have achieved this goal?" When devising a plan of action, the more efficient thinker thinks, "How can I tell if I am making mistakes in carrying out this plan of action?" After a plan of action has been carried out, the more efficient thinker examines the results to decide if the problem has been solved.

Less efficient thinkers carry out a plan of action and accept the results. They give little consideration to whether the results are correct or to whether the problem has been solved.

This is one of the most important ideas in problem solving. It is very easy to have an error in one's planning on how to solve a problem. It is very easy to make a mistake in carrying out a plan. Thus, it is essential that you develop good skills at examining the results of your problem-solving efforts. Many students neglect this final step in solving a problem! They produce answers that are "obviously" wrong, but they fail to think about their answers. Thus, they fail to detect obvious errors.

12. Unexpected Side Effects

The steps you take to solve a problem may lead to bad side effects. That is, new problems may be created. This can happen even if you think very carefully before carrying out your problem-solving plan. Once the original problem has been solved, you have a new problem situation.

More efficient thinkers recognize that a new problem situation has been created in the process of solving a problem. They examine the new problem situation to see if it leads to new, important problems.

Less efficient thinkers do not think about the side effects of solving a problem. Once the plan of action has been carried out, they tend to forget about the whole thing.

Begin ✍✍ (You may want to write in your journal.)

Think about the ideas discussed in Sections 11 and 12. Do they apply to you? Give examples in which you exhibited "more efficient" thinking. Give an example of a problem you solved where the results created an even harder problem.

End ✍✍

CHAPTER 6 SUMMARY

One way to get better at solving problems is to get better at thinking. More efficient thinkers make efficient use of their brains. They have a number of thinking-skill habits that relate to the steps one follows in solving problems. Some very important good thinking habits include:

1. Valuing education and working to get a good education.
2. Having good skills in developing and revising goals.
3. Having good skills in developing resources and in knowing appropriate restrictions.
4. Being good at thinking about possible outcomes from carrying out a plan of action.

You can become a better thinker and problem solver if you identify your less efficient thinking habits and consciously work to improve them.

Activities

1. Pick some idea you thought about while reading this chapter. Perhaps you thought about some of your more efficient thinking habits. Perhaps you thought about the fact that you have some less efficient thinking habits. Perhaps you thought about a problem where you displayed more efficient thinking skills. Write several paragraphs in your journal about some idea you thought about. You might want to use the following outline.

    1. Make a title for this journal entry. Your title might look like this:

    CHAPTER 6 ACTIVITY 1
    AN IDEA I HAD WHILE I WAS READING CHAPTER 6

    2. Write down and explain the idea.

    3. Explain why the idea interests you. Why did you remember this idea?

    4. How does this idea relate to things you do outside of this class?

5. What else do you think about when you think about this idea?

2. Get together with two or three other students in the class. Each of you is to select one idea from this chapter that seems particularly important to you. Each of you is to spend a minute or two talking about the topic. Why did you select it? Why is it important to you? What difference does it make in your life?

   In talking about your topic, try to make use of some of the new terms introduced in the earlier parts of the book.

3. Make up a short quiz of lower-order thinking skill questions for this chapter. (Include correct answers. Often a lower-order skill question has only one correct answer.) Your quiz should consist of questions that can be answered by a person who has a low level of knowledge of the material in this chapter.

   Then try out your quiz on two students in your class.

4. Make up a short quiz of higher-order thinking skill questions for this chapter. (Think about several possible correct answers. Remember that a good higher-order skill question is likely to have many different correct answers.) Your quiz should consist of questions that can be answered by a person who has a good understanding of the material and ideas in this chapter.

   Then try out your quiz on two students in your class.

5. Consider the idea of changing the number of minutes between classes in your school. List several possibilities, such as decreasing the time by one minute, increasing it by one minute, or increasing it by five minutes. Give arguments for and against each possibility.

6. Consider making the periods in your school longer or shorter. This is similar to the idea contained in Activity 5. In both cases we are working on the idea of dealing with alternate approaches to the same problem, of seeing differing points of view and giving arguments to support each point of view. What would other students think? What would teachers think? What would parents think?

7. Consider the 12 thinking-skill habits described in this chapter. Your problem is to order them on the basis of how good you are at them. The first item on your list should be the thinking-skill habit you are best at.

One way to do this is to first break the problem into three smaller problems. For example, first put each item in the list into one of three categories:

Category A: My best thinking-skill habits. (Put two or three in this list.)

Category B: My mid-range thinking-skill habits. (Put four or five in this list.)

Category C: My poorest thinking-skill habits. (Put two or three in this list.)

Now continue by ordering the items on each of the shorter lists. As you do so, you may find that you have changed your mind and that an item needs to be moved from one list to another.

8. Consider one of the items near the bottom of the list that you created for Activity 7. Think about whether you would like to be better at this type of thinking. If not, pick some other item from the lower part of the list. Find one that is important to you.

   Then think about some ways you could begin to do more of the things that "more efficient" thinkers do related to this item. Make a brief written list. Think about some situations that will occur today or later this week when you will get a chance to practice these ideas. When you get a chance to practice, do so. As you do so, think about the fact that you are practicing an important thinking skill.

Chapter 7
Transfer of Learning

ORGANIZE YOUR THINKING

Learning is a way to prepare for the future. You can learn about a type of problem situation at one time and place. You can then use this knowledge to deal with a problem situation at a different time and place. When the two problem situations seem nearly the same to you, this is called a "near transfer" situation. When the two problem situations do not seem much alike to you, it is called a "far transfer" situation.

- Near transfer is easy. Your mind does it automatically, with little conscious thought.

- Far transfer is harder. You can get better at far transfer by study and practice. Getting better at far transfer will make you a more efficient learner and a better problem solver.

Introduction

One of the most important ideas in problem solving is to build on your previous work. You have learned a lot. When a new problem situation comes up, you want to use ideas you have learned before. But what if the new problem situation is a little different than the old ones?

For example, when you were very young you learned to tie your shoes. This probably took you a lot of time and effort. Of course, now it is easy.

When you get new shoelaces or a new pair of shoes, you automatically know how to tie them. These new "bow-tying" problems are nearly the same as the bow-tying problem you learned to solve when you were very young.

But how about tying a bow on a holiday package you are wrapping? It is somewhat the same, but somewhat different. Or how about tying a bow tie? It is somewhat the same, but quite a bit different. How about tying a square knot in a rope? It is somewhat the same, but somewhat different.

Sometimes it seems that a new problem situation is nearly the same as one you have encountered before. Your mind seems to automatically recognize the situation. You remember what you did before and how well it worked. This helps a lot in dealing with the new problem situation.

At other times it seems like a new problem situation is really new and different. Your mind does not relate it to some problem situation you have encountered before. You feel like you are faced by a completely novel situation.

In the first case, your mind quickly recognizes that the new problem situation is nearly the same as a problem situation it has dealt with before. It does this without conscious thought. This quick recognition situation is called a **near transfer situation**. The brain quickly and easily transfers what it learned in the first situation to the new, present situation.

In the second case, your mind does not quickly and easily recognize that the new problem situation is similar to one it has encountered before. The new problem situation seems far removed from what you have previously learned. This is called a **far transfer situation**.

Each person's mind is unique. Each person's experiences are unique. Thus, what is a near transfer situation for one person might be a far transfer situation for another person. For example, consider the following lines of poetry written by Joyce Kilmer.

I think that I shall never see
A poem as lovely as a tree.

In Joyce Kilmer's mind, a poem can be lovely and a tree can be lovely. The two different lovely things are closely related in his mind. Does your mind work like Joyce Kilmer's?

Begin ✍✍ (You may want to write in your journal.)

Think of several near transfer problem situations you have dealt with in the past day. For example, perhaps you used a fork to eat some cafeteria food. Probably you have never used this particular fork before, and certainly you have never eaten that specific food before. You employed near transfer.

Think of a problem situation you have recently encountered that seemed like a far transfer situation to you. Pick a situation in which you were able to make a far transfer. For example, perhaps you used ideas from a school science class to solve a problem at home. Perhaps you used ideas from a math class to solve a problem in your health class.

End ✍✍

Some Brain Theory

Think about what happens when you come into a room full of people. You glance around to see if you recognize anybody. With little conscious thought, you recognize your friends. Your visual system is very good at recognizing the people you know well.

Your brain is very good at recognizing patterns even when they are not quite the same as a pattern it has stored. You can recognize a friend even when your friend has a new haircut and different clothes. You can recognize people you haven't seen for many years, even though they have gotten quite a bit older and their weight has changed. This happens quickly and easily, without conscious thought. It is a near transfer.

Your brain is very complex. It contains many billions of neurons. Each neuron can have connections to many thousands of other neurons. The neurons and the connections between the neurons store patterns. Your brain stores visual patterns, sound patterns, taste patterns, and so on.

Your brain is designed to be good at matching stored patterns with new patterns. You recognize a friend because your brain has stored a pattern of your friend's face. When you look at a person, your brain automatically begins to match what it is seeing with the stored patterns. If it detects a close match, you "recognize" the person. Sometimes your brain will make a mistake, and you will think that you recognize someone when you don't.

Also, recognizing a person and recalling that person's name are two different things. Your brain patterns for people's faces are stored in a different place from your brain patterns for their names. Most people find that they are much better at recognizing a person's face than they are at remembering the person's name. But some people are the other way. They may remember a person's name and a great deal about the person but not be able to describe the person.

Begin ✍✍ (You may want to write in your journal.)

You can see and recognize a picture of a person, and then try to remember that person's name. Or you can see a person's name, and then try to picture what that person looks like. Which are you better at?

Try an experiment. Picture one of your friends in your head, without thinking of his or her name. Can you do this? Then think of a different friend's name, without picturing the friend in your head. Can you do this?

Get together with a couple of other people from your class. Discuss the results of the name-versus-face activities. It what ways were your results alike? What were major differences?

End ✍✍

Brain researchers study the types of ideas discussed in the previous paragraphs. They have learned some things about the brain that can help you a lot. They have learned that the brain "learns" by building new connections among neurons. A brain gets "better" by building more connections and practicing using the connections. The more varied and "richer" the connections, the better the brain is at dealing with new, varied situations.

This helps us to understand the learning process. When you learn something new, your brain is building some new connections among neurons. When you learn something new, you want to build neural connections with lots of the things that you already know. This will help you to recall the new information at a later date, and it will help in the transfer of the new learning.

The Importance of Words

Words are very important in helping learning and transfer of learning. Here is an example. When you were in grade school, you learned that data can be represented using a pie chart. A pie chart looks somewhat like a pie cut into pieces.

What do the words "pie" and "chart" bring to your mind? When you think about the word "pie" do you think about food, dessert, cake, and being

hungry? When you think about the word "chart" do you think about a poster hanging on the wall?

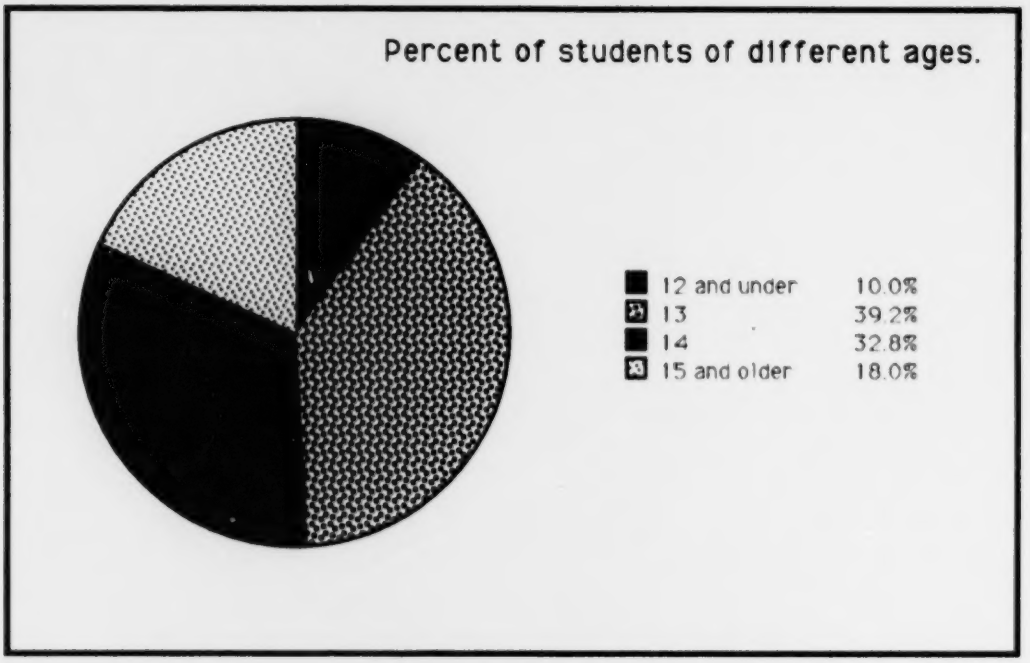
The expression "pie chart" is not a particularly good choice of words. It does not suggest ideas that are closely related to this way of representing information.

Another (better) name for "pie chart" is "circle graph." You may be familiar with several types of graphs, such as bar graphs, line graphs, and pictographs. Each of these types of graphs offers a way to represent information. They are all closely related. Thus, it helps to have their names be closely related. This helps you to transfer knowledge and skills from one type of graphing situation to another type of graphing situation.

A circle graph is useful in showing how something is divided into parts. For example, think about a school that has 250 students. Most are 13 or 14 years old, but some are younger and some are older. What percentage of the students fall into each age group?

A circle graph gives a picture of this data. The human visual system is very good at processing this type of picture information. Therefore, a circle graph is useful in representing types of data as "parts of a whole."

Age Range	**Number of Students**
12 and under	25
13	98
14	82
15 and older	45
Total	250



Learning for Near and Far Transfer

This section contains a little bit of **learning theory**. It tells how your brain works when it learns new things. You can think about your own learning processes. You can learn how you best learn new things. It is very important that you understand how to help yourself learn.

Here are two different approaches to learning something:

Type 1 Learning: Learning for near transfer. In learning something new, focus your attention just on the new material. Work to build just a few neural connections. Practice using these connections over and over again so that you can do the new thing very rapidly and accurately. Build a few, very strong, well-practiced neural connections.

Type 2 Learning: Learning for far transfer. In learning something new, focus your attention both on the new material and lots of different things that seem related. Work to build a large number of neural connections. Connect the new ideas to lots of different things you already know. Build a very large, "rich" set of neural connections.

The first approach is very important if you need to be able to do something rapidly and accurately, perhaps with little conscious thought.

You practice the information or skill over and over again. Eventually you get very good at it. You can respond rapidly and accurately to a situation that is nearly the same as the situation you have studied.

Of course, it takes a lot of time to do this. Also, you are not building neural connections to other ideas that you know. Therefore, your brain is less apt to recognize a new situation as being "near" to the old situation you have learned so well.

The second approach helps far transfer. When your brain encounters a new problem situation, it searches for stored patterns that are somewhat similar to the new situation. The richer and more varied the neural connections to the problem situations you have previously studied, the more apt your brain is to find a related pattern. But of course, it takes a lot of time to build this rich and varied set of neural connections.

In some learning situations it is necessary to take the Type 1 Learning approach. Very good examples come from the "fundamentals" in sports. To perform well, you must train your brain to respond rapidly and accurately to certain situations that occur over and over again.

But in most learning situations, a balance between the Type 1 and Type 2 approaches is important. You get better at problem solving by getting better at transferring your learning to new problem-solving situations. You improve transfer of learning by carefully and consciously building a rich and varied network of neural connections.

Begin ✍✍ (You may want to write in your journal.)

Think about Type 1 Learning and Type 2 Learning. Which do you think you are better at? Why?

Which do you think is more useful in learning to solve school problems? Why?

Which do you think is more useful in learning to solve problems that occur outside of school? Why?

End ✍✍

Examples of Type 1 and Type 2 Learning

Graphing is a very important way to represent data. Thus, math teachers know that circle graphs are very important. But many students find that it is hard to learn how to draw a circle graph. To draw a circle graph, you need to work with percentages. This requires long division. You need to know that a circle contains 360 degrees. You need to figure out different percentages of 360 degrees. This requires multiplication and working with decimals. You need to learn how to use a protractor to measure degrees and a compass to draw a circle.

Because of all of these difficulties, many students find that it is hard to learn to draw a circle graph. When this topic is being taught in a math class, the math teacher may place most of the instructional effort on practicing each of the detailed steps required in making a circle graph. This is like the Type 1 Learning described in the previous section. It prepares you to accomplish the specific task of making a circle graph.

Also, you know that you are going to be tested on circle graphs, so you practice on them until you know you can pass the test. You place considerable emphasis on Type 1 Learning. You have a (near transfer) goal of being able to draw a circle graph on the next test.

Now think about what happens in your social studies class a few weeks or months after you have studied circle graphs in math. The teacher is talking about income levels. Perhaps the class is looking at data about how many people earn less than $10,000 per year, how many earn between $10,000 and $15,000, and so on. Does it occur to you that this would be a good place to use a circle graph?

For some students, the answer is clearly "no." For some students, the income-problem situation in a social studies class is a far transfer situation from the circle-graph problem situation in a math class. Their learning efforts in the math class were so concentrated on Type 1 Learning that little time was spent on Type 2 Learning. They did not spend time and effort building a rich and varied set of neural connections. Their brains fail to detect that the pattern of data in the social studies class is like the pattern of data in the math class. Thus, their brain is unable to realize that a circle graph would be useful in the social studies class.

Begin ✍✍ (You may want to write in your journal.)

The need to draw a circle graph can occur in many different courses. Make a list of situations where a circle graph would be useful. Is drawing a circle graph a primitive for you?

How long do you think it would take you to draw a seven-piece circle graph, starting with the seven pieces of data? You might want to do an experiment. Make an estimate of how many hours per week you spend in each of the following categories. (The total number of hours in a week is 7 x 24 = 168.) Then draw a circle graph of your data. Time how long it takes you.

1. Sleeping.
2. Going to school and doing homework.
3. Watching television, listening to the radio, and listening to recordings.
4. Eating.
5. Talking to friends.
6. Getting to and from places (transportation).
7. Miscellaneous other activities.

End ✍✍

Concepts and Procedures

The circle graph example illustrates a very important idea about learning. It is an idea we talked about in a previous chapter when we defined the idea of a primitive. There are two very different things to learn about circle graphs:

1. The "concept" or underlying ideas in a circle graph. A circle graph gives a picture of the "parts of a whole." It is a good way to represent the pieces of something so that a person can see their relative sizes.

2. The steps (processes, procedures) you must carry out to draw a circle graph. To draw a circle graph by hand requires a good working knowledge of quite a bit of math.

Your brain is quite capable of learning the concepts of a circle graph and how to do the procedures to draw a circle graph. However, a computer can

easily, quickly, and rapidly convert data into a circle graph. The computer can do the "procedure" part of drawing a circle graph. This means that drawing a circle graph can become a primitive for you if you learn the mental concept of circle graph and have access to a computer. A circle graph is a good example of a computer primitive.

Begin ✍✍ (You may want to write in your journal.)

Is it easier for you to draw a circle graph or a bar graph? (In a bar graph, the heights of the bars represent the numbers to be displayed.) In what ways are the concepts of a circle graph and a bar graph nearly the same for you? In what ways are they different?

Have you used a computer program that can draw a circle graph? Usually, the same program can also draw a bar graph and a line graph. Once you enter the data into the computer, just a few keystrokes are needed to output it in any one of the graphical forms. How might this help you to solve problems?

End ✍✍

Learning to Increase Far Transfer

How many times have you sat in a school class and thought, "I wonder what good this is to me? It doesn't seem to have much to do with me and what I am interested in right now."

Such questioning is a good start in increasing far transfer. As far as your brain is concerned, everything can be related to everything. A poem and a tree can be closely related. But it is up to you to tell the brain what neural connections to build. You can do this by making a conscious effort to do so. You "tell" your brain to build neural connections by "thinking" about how things are related. If you want neural connections that relate a poem to a tree, you must consciously think about how a poem and a tree are related.

Only you can make up a good answer to the question "I wonder what good this is to me?" Everything you learn can be related to other things you already know. The efficient thinker consciously builds many neural connections. The efficient thinker finds many answers to the "What good is this?" question.

Begin ✍✍ (You may want to write in your journal.)

Let's practice a little. Think of ways in which a cat and a dog are related. Then think of ways in which a cat and a tree are related. Then think of ways in which a dog and a tree are related.

Suppose you had started with the task "Think of ways in which a dog and a tree are related." Would you have produced the same connections as you got in the previous paragraph? Why or why not?

End ✍✍

Let's go back to the circle-graph example. The math teacher stresses that there are several important ideas (underlying principles) in circle graphs:

1. In many problems, it is important to think about "parts of a whole."

2. A circle graph is a good way to represent parts of a whole.

You can listen to what the teacher is saying. You can memorize the expression "parts of a whole" and understand that a circle graph is useful in representing parts of a whole. You can concentrate on the Type 1 Learning that will help you pass a test in which you have to draw a circle graph.

But there are two things wrong with this approach. First, little of the Type 2 Learning will occur. You will not develop the rich and varied neural connections needed to help far transfer.

Second, you will be spending your time learning to do things that a computer can do! A computer can take a table of data and draw a circle graph of it. A computer can do this accurately and rapidly. A computer can do it far more accurately and rapidly than even a well-trained human.

Remember the question we asked early in this book. If a computer can solve or help solve a type of problem, what should a student learn about solving this type of problem? We are beginning to develop an answer. In the circle-graph example, there are two different types of learning going on. Type 1 Learning helps the brain to become machine-like. It concentrates on learning a procedure. It helps the brain become fast and accurate at doing the procedure. But often the procedure is one a machine can accomplish much better and faster than a human.

On the other hand, Type 2 Learning helps the brain learn to respond to new and varied situations. It stresses learning concepts or underlying principles. It stresses how the general ideas can be used in a wide variety of problem situations. Such learning promotes far transfer. Humans are very good at this. A human can learn that a poem and a tree are related because both are lovely. A human can know and understand what it means for something to be lovely. Humans are far better than computers at this type of task.

CHAPTER 7 SUMMARY

You can get better at far transfer by study and practice. When you are learning how to solve a new type of problem, think about the following questions:

1. What are the underlying concepts or principles?

2. How are these concepts related to other things you already know? (Do metacognitive thinking that will increase far transfer.)

3. What are the procedures needed to solve the problem?

4. Can a computer or other machine help carry out these procedures?

Activities

1. Pick some idea you thought about while reading this chapter. Perhaps you thought that "transfer" is an interesting idea. Perhaps you wondered why some teachers place so much emphasis on learning for near transfer. Perhaps you thought of ways that a cat and a poem are connected. Write several paragraphs in your journal about some idea you thought about. You might want to use the following outline.

    1. Make a title for this journal entry. Your title might look like this:

    CHAPTER 7 ACTIVITY 1
    AN IDEA I HAD WHILE I WAS READING CHAPTER 7

    2. Write down and explain the idea.

3. Explain why the idea interests you. Why did you remember this idea?

4. How does this idea relate to things you do outside of this class?

5. What else do you think about when you think about this idea?

2. Get together with two or three other students in the class. Each of you is to select one idea from this chapter that seems particularly important to you. Each of you is to spend a minute or two talking about the topic. Why did you select it? Why is it important to you? What difference does it make in your life?

   In talking about your topic, try to make use of some of the new terms introduced in this chapter. A list is given below. Remember, definitions are given in the Glossary.

   far transfer situation
   learning theory
   near transfer situation

3. Make up a short quiz of lower-order thinking skill questions for this chapter. The idea of lower-order thinking skills is discussed in the Glossary. Include correct answers with your questions. (Often a lower-order skill question has only one correct answer. It asks for a simple fact or a low level of understanding.) Your quiz should consist of questions that can be answered by a person who has a low level of knowledge of the material in this chapter.

   Then try out your quiz on two students in your class.

4. Make up a short quiz of higher-order thinking skill questions for this chapter. The idea of higher-order thinking skills is discussed in the Glossary.

   Think about several possible correct answers for the questions you write. Remember that a good higher-order skill question is likely to have many different correct answers. It asks about complex relationships. It may ask a person to put together two or more ideas. Your quiz should consist of questions that can be answered by a person who has a good understanding of the material and ideas in this chapter.

   Then try out your quiz on two students in your class.

5. This is a journal-writing activity. Select three different subjects you are taking.

   1. Make a title for this journal entry. Your title might look like this:

CHAPTER 7 ACTIVITY 5
CONCEPTS AND PROCEDURES IN THREE SUBJECTS

   2. For each subject, give an example of a concept and an example of a procedure that is important to learn in that subject.

   3. Which of the subjects seems to involve the most time on learning concepts? Why do you think the subject does this?

   4. Which of the subjects seems to involve the most time on procedures? Why do think the subject does this?

6. This is a journal-writing exercise. You know how to multiply big numbers together. For example, you know how to do the calculation:

5293 x 718

Perhaps you know the concept that multiplication is a fast, shorthand way to do repeated addition. (Imagine adding up a column of 5293s that is 718 lines long!)

While you were in grade school, you learned a paper-and-pencil procedure to do multiplication of whole numbers. If you are like most students, you have spent many dozens of hours practicing this multiplication procedure. You can do it fairly rapidly and fairly accurately.

   1. Make a title for this journal entry. Your title might look like this:

CHAPTER 7 ACTIVITY 6
TRANSFER IN MULTIPLICATION

   2. Discuss how the things you have learned about multiplication of whole numbers transfer to learning to do multiplication of decimal fractions, for example:

3.73 x 89.413

Your discussion should involve both concepts and procedures.

3. Discuss how the things you have learned about multiplication of whole numbers transfer to learning to do multiplication of fractions, for example:

$$3\ 5/6 \times 8\ 3/4$$

Your discussion should involve both concepts and procedures.

7. One very important idea in problem solving is self-confidence. Some people "know" that they are good at solving problems. When they encounter a new problem situation, one of their resources is self-confidence. This self-confidence is a resource that transfers to every problem situation they encounter.

   Think about your level of self-confidence as a problem solver. Is it as high as it could be? What might make it higher? Think of an idea for improving your self-confidence as a problem solver. Practice it several times a day.

Chapter 8
Modeling

ORGANIZE YOUR THINKING

A model, such as a scale model, can serve in place of the "real thing" to help you solve problems. There are different ways to model (represent) a problem. One way is in your head—a mental model. A second way is by talking—a verbal model. A third way is by using writing and pictures. Still another approach is to model a problem inside a computer.

You can get better at problem solving by:

- Learning a number of different ways to model a problem.
- Practicing using different models. Learn when one is better than another for you.
- Learning to develop and use computer models of problems.

Introduction

In order to solve a problem, you must understand the problem. You must represent the problem in your mind, so you think about it. You must pick out important aspects of the problem. You must think about how the important parts relate to things you know.

A representation of a problem is called a **model** of the problem. There are many different ways to model a problem. For example, you might build a scale model or draw a picture to represent a problem. You can think of a blueprint of a building as a model of the building. You might model a problem by using words or mathematics. Each different type of model has certain advantages. A type of model that is very useful for one kind of problem might not help on a different kind of problem.

In this chapter we will examine a number of different types of models. Each type of model has certain especially useful features. We will suggest several ways in which computers can be used in modeling problems. Use of

computers in modeling is a very powerful aid to solving many different kinds of problems.

Mental Models

You can solve many problems in your head. You think about a problem. You consider different things you might do to solve the problem. In your mind's eye you can see the steps needed to reach the goal. You imagine carrying out these steps and the possible results. As you work on the problem, new ideas occur to you. You make changes in your mind.

Think about a problem you dealt with yesterday. Get the problem clearly in mind. (Don't read the next paragraph until you have a specific problem in mind!)

Pretend you are explaining the problem to yourself. Represent the problem using words and pictures in your mind. What feelings does the problem bring to mind? Perhaps you can even recall smells and tastes associated with the problem.

You have just created a **mental model** of a problem. It is a mind picture—a mental representation. A model is not the same as the object or idea being modeled. A mental model of a problem is not the same as the problem. But a model can represent some of the important parts of a problem. It can help you to solve a problem.

You can use a mental model to think about a problem. You can use it to consider possible actions. In your mind's eye you can see what might happen if you carry out the actions. Mental modeling is part of thinking. It is very important in problem solving.

Begin ✍✍ (You may want to write in your journal.)

Do some metacognition about the mental model you formed earlier in this section. Was your mental model mainly pictures? Was your mental model mainly words and sounds? Sometimes a "picture" mental model is most useful. At other times, a "words and sounds" mental model may be most useful. At still other times, a "feelings" model may be most useful.

Think about a cow. When you think about a cow, does a picture of a cow form in your head? Does a "mooing" sound form in your head? Does the

smell of a barnyard form in your head? Does a good feeling form in your head? The mental models you form depend on the experiences and training you have had.

Think about a cold, windy day. Do metacognition on your mental model. Then think about being lost in a desert. Do metacognition on your mental model.

End ✍✍

Your mind is very powerful. It can form a mental model of anything you want to think about. If you want to think about a cloud, your mind forms a mental model of a cloud. If you want to think about a polka dotted cow, your mind forms a mental model of a polka dotted cow. With a little effort, you can even form a mental model of polka dotted milk coming from such a cow!

Verbal Models

It is very helpful to be able to share your mental models with other people. One way to do this is by talking. You can form a **verbal model**. You can use spoken words and other sounds to represent your mental model. A verbal model may also include "body language." A great deal of information is communicated through facial expressions, hand movements, and so on. Sometimes people call a verbal model a **verbal/body-language model** to emphasize that both sounds and body language are involved in the communication.

Probably you are good at talking. However, sometimes it is hard to find the right words. Can you find words to describe the taste of good food? Can you find words to describe what it is like to be with a good friend? Sometimes it is not easy to give a good verbal model of what is in your head.

Thinking and talking are closely related. When you are thinking, you are doing silent talking—you are talking to yourself. Talking out loud helps you to organize your thoughts. It is a way of practicing your thinking. You can get better at thinking by getting better at talking. Words are an aid to thinking. That is why vocabulary and talking using the vocabulary are stressed in this book.

Researchers have found that talking about what you are learning is a powerful aid to learning. Teachers have known this for a long time. They learn a lot about the subject they teach by talking about it with students. You can learn by explaining new ideas to your friends.

Begin ✍✍ (You may want to write in your journal.)

This is a game that can be played in small groups. Get together with two other students in the class. One person is to be the "sender" and the other two are to be the "receivers." The sender forms a mental model of a person, place, or thing. Then the sender begins to give a verbal model of the object, but without naming it.

The goal is to give a very good verbal model. As soon as the receivers are sure they know the object, they write it down. The game ends when both receivers have written down the name of the object. When a game ends, check to see if the answers are correct. Talk about which clues were most helpful. Then have someone else become the sender.

The same activity can be used with the sender drawing a picture. It can also be played using nonverbal modeling—just acting out the object. Several television game shows use these ideas.

End ✍✍

Written Models

The invention of reading and writing is undoubtedly the single most important event in the history of education. Writing—using letters, digits, punctuation, diagrams, and so on—is a way to model spoken language. We will call this a **written symbolic model**, or simply a **written model**. When you write, you are creating a written model. When you draw a picture of an object, you are making a written model of the object.

The process of writing is very closely related to thinking. Writing helps your brain to think. Writing helps you to organize your thoughts. Writing is a very important aid to problem solving. To be a good writer, you must be a good thinker.

Writing has additional values. It is an aid to your memory. Thus, you can form a written model that is much more complex than you can hold in your active, conscious memory. This written model can be stored for later use. Copies can be made for other people to use.

The Early Beginnings of Writing and Math

Researchers have discovered on cave walls drawings that are more than 15,000 years old. At that time all people got their food by hunting and by gathering wild fruits, vegetables, and grains. The cave wall drawings can be thought of as written models. Perhaps they helped people to remember successful hunts and other special events.

More than 10,000 years ago some people began to be farmers. They learned to plant crops and raise farm animals. But this led to many hard problems. When do you plant your crops? When do you harvest your crops? How many animals do you have? (Did a wolf get one last night?) How much grain do you have in storage? Is there enough to last through the winter? How many days before planting season begins?

Numbers and written languages were developed to help solve these problems. Perhaps written numbers came first, and then written words. The very earliest written languages used pictures to stand for ideas or words. A picture of a sheep could stand for a sheep. A simple stick figure of a person could be used to represent a person.

But how do you represent an old person, a child, a baby, a female baby, and so on? How do you represent your relatives and their relationships to you? It is easy to see why languages contain so many words.

The development of writing led to a major turning point in education. Every community could benefit by having some people who could read, write, and do arithmetic. But it takes a long time for a person to learn reading, writing, and arithmetic. It really helps to have a teacher when you are learning reading, writing, and arithmetic. The teacher needs to have a great deal of knowledge about teaching and learning.

The Growth of Information

Reading, writing, and arithmetic help in the storage of information. If one person figures out how to solve a problem, that person can write it down. Others can then learn to solve the problem by reading what was written.

Reading, writing, and arithmetic help humans to accumulate knowledge. Have you ever wondered why there are so many different subjects in school? Why do we have art, music, health, physical education, math, science, and so on? Each subject deals with different kinds of problems. The problems in art are quite a bit different than the problems in biology or in health. There is a great deal known about the problems in each subject.

People working in a subject want to write precise descriptions of the problems. They want to write precise descriptions of how they try to solve the problems. They want to give examples of the problems they know how to solve. This leads to each subject having its own special words and its own special symbols. This helps the workers in the field to write very precise written models for use in their field.

One major goal in each subject you study is to learn to make verbal and written models for the problems in that subject. This means that it is very important to learn the vocabulary. It is very important to practice talking and writing about the ideas in the subject.

Begin ✍✍ (You may want to write in your journal.)

Think about the problem of communication in music. Musicians have developed musical notation and special vocabulary to help them form symbolic models. Think of some other subject that uses special notation and words. Give some examples of the notation and special vocabulary.

End ✍✍

Written Models Help Your Mind to Store and Process Information

The neurons in your brain do two different things. They *store* information and they *process* information. Your mind is both a storage device and a processing (a thinking) device.

This is a key idea. It suggests two kinds of aids to the mind. One kind is a storage aid. The other kind is a processing aid. For example, a dictionary is a storage aid. A hand-held calculator is a processing aid.

It is possible to have a combined storage and processing aid. For example, writing with paper and pencil is a storage aid. But it is also a

processing aid. Writing helps you to organize and then reorganize your thoughts.

Using paper and pencil to do arithmetic provides another example. Think about doing a paper-and-pencil long division. You make use of writing as a temporary storage aid. You also use the writing to help you process the math symbols.

Begin ✍✍ (You may want to write in your journal.)

Think of some problems where you have used aids to your brain's storage capacity. For example, do you write down the addresses and phone numbers of your friends?

Think of some problems where you have used aids to your brain's processing capabilities. For example, do you make use of a hand-held calculator?

End ✍✍

Scale Models

There are many other kinds of models that can help you to solve problems. For example, you have seen **scale models** of cars, airplanes, and houses. A scale model of a office building can be used to help design a office building. What will the office building look like when it is built? How will it fit into the landscape? Will people find the office building attractive?

Airplane designers build scale models of airplanes. A scale model of an airplane can be used in a wind tunnel to test the shape of the body and wings. How much air resistance will there be? This is much cheaper than building an entire airplane and then seeing how well it flies. Also, it is much safer!

Begin ✍✍ (Please write in your journal.)

Please do the following journal-writing activity. Use a title line such as the following:

EXAMPLES OF USING KINDS OF MODELS

1. Give an example of a time when you used a mental model to help you solve a problem.

2. Give an example of a time when you used a verbal model to help you solve a problem.

3. Give an example of a time when you used a written model to help you solve a problem.

4. Give an example of a time when you used a scale model to help you solve a problem.

5. Think of other types of models you have used to help you solve a problem. For each, give an example of the type of problem you were solving. For example, a budget is a model used to deal with a money problem. A map is a model used to help find out how to get some place. A recipe is a model used to help solve a food problem.

End ✍✍

Mathematical Modeling

You may have wondered why you have to take so much math in school. The reason is that math is an important general purpose aid to modeling many different kinds of problems. How much money do you have with you right now? The answer—a number—is a **mathematical model** for your money.

Think about a carpenter building a table. The table will have a rectangular top with a molding around it. The carpenter is thinking about how much material will be needed. Here is a written model for this problem.

The area of the table top is the length times the width.
The perimeter of the table top is twice the length plus twice the width.

Now think about a farmer who is planning a field that needs to be of a certain size. The farmer is planning a rectangular field. Here is a written model for this problem.

The area of the field is the length times the width.
The amount of fencing needed to enclose the field is twice the length plus twice the width.

Mathematicians have spend a lot of time thinking about such written models. They notice that the two written models are nearly the same. Consider the following math formulas.

Area = Length x Width
Perimeter = 2 x Length + 2 x Width

These math formulas are a mathematical model for the carpenter's problem and the farmer's problem. But even these simple formulas are too "wordy" if they are to be written over and over again. Thus, mathematicians have developed abbreviations for these formulas.

$A = LW$
$P = 2L+2W$

These examples illustrate two very important points:

1. The experts in a field develop special vocabulary, special notation, and special abbreviations to represent the written models of their field. So, if you want to read and use the models in a special field, you need to learn the vocabulary and notation of that field.

2. The same math model can be used for a number of different problems. A set of math formulas can be a model that helps solve a problem for a carpenter or a farmer. This helps in transfer among fields.

But there is still one more important point to make about this example. The math model for a rectangle does not say anything about the material to be used. It says nothing about the type of wood the carpenter will use. It says nothing about the type of fencing material the farmer will use. The formulas are a model for just two aspects of a rectangle—its area and the distance around it.

This is a very important idea. A model is a representation of certain aspects of an object. If you want to study these aspects, the model may help. However, the object being modeled has many features that are not in the model. If you want to study these features, the model will not help.

Begin ✍✍ (You may want to write in your journal.)

Give several examples of uses of the math model formulas for a rectangle. For each one, give at least two examples of important features that these math formulas do not include.

For example, the area formula is a useful model in working on the problem of painting the floor of a room. But the formula does not give information about the color to be used, what quality of paint to use, how long it will take to dry, and so on. The perimeter formula is useful in fencing a parking lot. But it does not tell us anything about the height of the fence, the type of material to be used, or how attractive the fence will be.

End ✍✍

Computer Models

The computer was invented as an aid to math modeling. The idea was that certain types of math formulas could be stored in a computer. The computer could automatically do the work of using the formulas. (Notice that the computer was invented as a *storage and processing* device.) The goal was to make it much easier to solve problems that require a great deal of computation.

Earlier in this chapter we talked about building a scale model of an airplane. We talked about using a wind tunnel and the scale model to test the design of a new airplane. In recent years scientists have developed another way to test the design of an airplane. They write formulas that describe the shape of the airplane. They write formulas that describe how the airplane will perform at different speeds. The formulas use math symbols. These math symbols can be put into a computer. This is called a **computer symbolic model**. To save words, we will usually just call it a **computer model**.

With a computer model, scientists can do the same types of tests they can do with a scale model and a wind tunnel. But in many ways a computer model is much better than a scale model. For example, it is easier to change a few formulas than it is to rebuild a scale model.

Soon after the first computers were built, people began to think of lots of uses for computer models outside the math field. They realized that a computer model could be used on many different kinds of problems. As computers have become cheaper and more widely available, more and more uses have been developed. That is, people have figured out more and more ways to make use of computer models to help solve problems.

Why Are Computers So Important?

A mental model is very useful in solving problems. A mental model is easy to change. You just "think" it different. You change the pictures in your head. Then you can think about solving a problem using the new mental model. You use your mind for both storage and processing in solving problems.

However, your mind has limitations as a storage device because it can easily forget things. It has limitations as a processing device because it gets bored and can easily make mistakes. Thus, it is important to have aids to your mind.

A written model is harder to create than a mental model. Also, it is harder to change than a mental model. But a written model is a good aid to storing and processing information. Also, it is more permanent, and it is possible to make a lot of printed copies. A written model of a problem can be shared with other people. This helps a number of people to work together on a problem.

It would be nice to have something that combines some good features from mental models and written models. You want to be able to build models that are easy to change, like a mental model. But you want something that will help your mind in storing and processing information. Also, you want to store information in a permanent, transportable, shareable form.

The electronic digital computer is an answer. A computer is an aid to both storage and processing. A computer model can be easy to change. A computer can process information that is in a computer model. Information in a computer can be shared and transported. These features make computer models very important.

For example, suppose you are working on a problem of writing a report. The goal is to do a very good job of writing. This means you will want to read your report very carefully. You will want to revise it so that it says

exactly what you had in mind. (You want your final written model to be a good representation of your mental model.) You also want to correct all the errors you find in spelling and grammar.

Now suppose you have a computer and a word processor to help you solve the writing problem. You type your report into a computer by using a word processor. With a computer, it is easy to make changes in your report. It is easy to insert new sentences to make the report clearer. It is easy to rearrange paragraphs if this is necessary. It is easy to correct errors in spelling and grammar.

Indeed, the word processor may contain a spelling and grammar checker. A spelling checker looks up every word in a dictionary. It does this rapidly and automatically. This is a type of processing that computers can do very well. Grammar checking is more difficult for a computer. However, even a relatively simple grammar checking program can help find errors such as not beginning a sentence with a capital letter.

Now you can begin to see the value of using a computer model. A computer model is easy to change. And, the computer itself may help you to decide what changes to make!

Some More Uses of Computer Models

The rest of this book is about computer models. You will learn about some of the kinds of problems that can be represented by computer models. Here are a few key ideas:

1. Some aids to computer modeling are very easy to learn how to use. A word processor is a good example. It is also easy to learn to use a computer to do graphics and to work with databases.

2. Some aids to computer modeling are useful in solving a wide variety of problems. A database is useful in every subject you might study in school.

3. Some aids to computer modeling are very specialized. For example, there are computer programs that help a person write music symbols. Think of this as a "music notation" processor, sort of like a word processor designed for use in music.

4. Many computer programs have been written to solve some important problems that occur over and over again. For example, consider the problem of finding spelling and typing errors in your writing. This is the problem a spelling checker is designed to help solve. This is an aid to your mind's processing abilities.

   Similarly, a computer can do much of the processing in solving many different math and science problems. There are thousands of computer programs that have been written to do this type of processing.

5. A computer can be very helpful in solving a lot of different kinds of problems. But there are many problems a computer cannot solve. It is important to understand limitations of computers.

The key to using a computer to help solve a problem is computer modeling. It is easy to see how to model a dictionary in a computer. One just stores all of the words in the computer memory. It is easy to see how to model the processing of checking for spelling errors. One just has the computer look up every word in its dictionary. Even here, however, you can begin to see some computer limitations. Consider the sentence, "I went two the store." A spelling checker will not tell you that "two" is incorrect in this sentence. The problem of developing a computer program to detect such errors has proven to be very difficult.

There are other much more important problems where computers are of limited value. How do you model human feelings in a computer? How do you model human values? How do you model the beauty of a setting sun or a silent evening? How do you model being in love? There are many things that cannot be modeled very well in a computer. A computer is not too useful in solving problems involving human values, feelings, and beauty.

Computer modeling is a very important idea. It is a powerful aid to problem solving. There are many problems that can be solved by computer modeling. But mental models are still the most important. Problem solving begins in your mind.

CHAPTER 8 SUMMARY

Modeling is a key part of problem solving. Mental modeling is most important. However, different types of models are useful in working on different aspects of a problem. A complex problem may require you to use a variety of different models.

Many different kinds of models can be represented inside a computer. Computer modeling may take advantage of a computer's:

1. Storage capability.

2. Processing capability.

A well-designed computer model is easy to change and it takes advantage of a computer's processing capabilities.

Activities

1. Pick some idea you thought about while reading this chapter. Perhaps you thought about how your mind seems to be good at developing mental models. Perhaps you realized you had not thought about modeling the way this chapter presents it. Write several paragraphs in your journal about some idea you thought about. You might want to use the outline given below.

    1. Make a title for this journal entry. Your title might look like this:

    CHAPTER 8 ACTIVITY 1
    AN IDEA I HAD WHILE I WAS READING CHAPTER 8

    2. Write down and explain the idea.

    3. Explain why the idea interests you. Why did you remember this idea?

    4. How does this idea relate to things you do outside of this class?

    5. What else do you think about when you think about this idea?

2. Get together with two or three other students in the class. Each of you is to select one idea from this chapter that seems particularly important to you. Each of you is to spend a minute or two talking about the topic. Why did you select it? Why is it important to you? What difference does it make in your life?

   In talking about your topic, try to make use of some of the new terms introduced in this chapter. A list is given below. Remember, definitions are given in the Glossary.

   computer symbolic model (computer model)
   mathematical model
   mental model
   model; modeling
   scale model
   written symbolic model (written model)
   verbal model
   verbal/body-language model

3. Make up a short quiz of lower-order thinking skill questions for this chapter. (Include correct answers. Often a lower-order skill question has only one correct answer.) Your quiz should consist of questions that can be answered by a person who has a low level of knowledge of the material in this chapter.

   Then try out your quiz on two students in your class.

4. Make up a short quiz of higher-order thinking skill questions for this chapter. (Think about some possible correct answers. Remember that a good higher-order skill question is likely to have many different correct answers.) Your quiz should consist of questions that can be answered by a person who has a good understanding of the material and ideas in this chapter.

   Then try out your quiz on two students in your class.

5. Do you have any loose change with you? The word "quarter" is a model for a particular piece of metal. But the same word has many other meanings. List a number of meanings for this word. When you are talking to someone and they say the word "quarter," how can you tell which meaning they have in mind? Do you think a computer could do this?

6. Imagine that you have a fresh apple in your hand. The apple is firm, juicy, and just the right ripeness. Imagine how good the apple will taste as you bite into it. In your head, make a mental model of an apple.

   What color of apple did you think of? How big was the apple? As you thought of this apple, did you think of anything else? For example, did you think about other kinds of fruit?

   Now give a number of examples of models of different aspects of an apple. For example, 14 ounces is a model of the weight of a rather large apple.

7. If a computer model can be developed for a problem, does this mean that a computer can solve the problem? Give examples and/or arguments to support your conclusion.

8. We use the Hindu-Arabic numerals 1, 2, 3, and so forth. The Romans used the numerals I, II, III, IV, V, and so forth. Compare and contrast these symbolic systems for representing math problems. For example, which is easier to learn? Which is best for doing very simple additions? Which is best for doing long division?

9. In what sense is a budget a model? Give a specific example of a problem you have solved by making use of a budget model.

10. Consider the saying "The map is not the territory." Think of a map as being a model. For example, a "globe" is a representation of the world. Explain some possible meanings of the saying "The map is not the territory."

Chapter 9
General Purpose Computer Tools

ORGANIZE YOUR THINKING

Some of the basics of education include reading, writing, and arithmetic. These are "tools" that help you to understand and solve many different kinds of problems.

There are some computer tools that are useful in solving a wide range of problems. Examples of these general purpose tools include:

- Word processor (modeling using writing).
- Database (modeling tables of data).
- Graphics (modeling using diagrams and pictures).
- Spreadsheet (math and/or business problem modeling).
- Networking (connecting computers with people and with other computers).

Introduction

A computer is a tool that can help your mind to solve problems. This chapter is about computer software that is useful in solving a wide range of problems. A word processor is a good example of such software. Writing is important in almost every subject area. Thus, a word processor is apt to be useful in almost every subject area you study.

In the previous chapter we focused on computer models. Remember, computer modeling is a useful aid to problem solving because:

1. A computer can be used to model many different types of problems. A computer is a versatile tool useful in modeling problems in every course you take in school.

2. Computer models are easy to change. The computer may be able to do much of the work in making a change.

3. A computer can automatically follow a detailed set of directions. Once a computer model has been developed for a problem, a computer may be able to do much of the problem-solving work for you.

In this chapter we look at several general purpose computer modeling tools. (The chapter is not designed to teach you how to use these tools. Other people have written books for that purpose.) We assume you have already used some of these pieces of software. You will learn to use others if you decide that it is worth your while.

Begin ✍✍ (Please write in your journal.)

Please do the following journal-writing activity. Use a title line such as the following.

GENERAL PURPOSE SOFTWARE

1. Make a list of general purpose problem-solving pieces of computer software you know how to use. Examples might include a word processor and a program for drawing graphics. For each one, give examples of the kinds of problems the software helps to solve.

2. Make a list of some general purpose pieces of computer software you have heard about but don't know how to use. For each one, give examples of the kinds of problems you think the software helps to solve. For example, perhaps you have heard of a spreadsheet but never used one. It is useful in solving business and math problems.

End ✍✍

User-Friendly Software

It is easy to learn to use a word processor. One reason is that the **human-machine interface** makes it easy. A human-machine interface is the hardware and software system that people use to communicate with a computer and that a computer uses to communicate with a person. If you

know how to read and write, you know most of the things you need to know to use a word processor. If you know how to use a typewriter, you know some additional things needed to use a word processor.

A word processor is designed to be easy to use and easy to learn how to use. It is designed to be **user friendly**. If software is user friendly, it takes advantage of what you have previously learned. It is "forgiving" of mistakes you might make in using the software. For example, a user-friendly piece of software will not destroy a project you are working on just because you happen to push a couple of wrong keys.

Begin ✍✍ (You may want to write in your journal.)

This activity assumes you have used a word processor. Name some ways in which a word processor is better (more user friendly) than pencil and paper as an aid to writing. For example, it is easier to correct mistakes. Name some ways in which pencil and paper are better (more user friendly) than a word processor as an aid to writing. For example, paper and pencil are much more portable.

Now think of a word processor that also contains a spelling checker. Compare and contrast it with pencil, paper, and a dictionary as an aid to writing.

Now think of a word processor that contains a grammar checker. Would this help you to be a good writer?

End ✍✍

Some Features of Good, General Purpose Software

There are thousands of computer programs that help solve problems. Some are especially designed to solve just one specific type of problem. For example, there are computer programs that can solve chess problems. (What moves do you make to win during the next three turns?) There are computer programs to train astronauts to fly spaceships.

This chapter focuses on some of the more versatile computer software. It discusses software with the following features:

F1. The software is useful in helping to solve many different kinds of problems from many different fields. It may be useful in every subject you study in school.

F2. The software is useful in working on the kinds of problems in which one needs to make many changes. The computer helps you to try different ideas and to see the results of your trials.

F3. The software takes advantage of the power of a computer to do quite a bit of work for you. Both the storage and the processing power of the computer are used.

F4. The software is easy to learn how to use and easy to use. It is user friendly. You can easily learn how to use the software to help solve the kinds of problems you are studying in school.

Many pieces of software have these features. In this chapter we will briefly discuss five types of software. In each case, we will look at examples of some of the kinds of problems that the software can help solve. Keep in mind that the computer is merely an aid to problem solving. You will need to do the underlying thinking!

Word Processor

A word processor has all of the features F1-F4 listed above. We assume that you have used a word processor, so we will not go into details on how to use one. Instead, we will look at some of the kinds of problems a word processor can help solve.

1. **Organizing your thoughts.** You can use a word processor to outline a paper. You can rearrange the outline ideas until they seem right to you. You can then expand the outline into a complete paper. As new ideas occur to you, they can be inserted into the paper wherever they belong.

2. **Revision.** Good writers know that one key to good writing is "Revise, revise, revise." A word processor is a very powerful aid to revision. This may involve just making small changes, such as correcting a misspelled word, or it may involve reorganizing entire sections and making major changes.

   It takes a lot of training and practice to get good at doing revision. Many students who have done all of their writing using pencil and paper are not good at doing revision They have not practiced it very much.

One reason is that it is a lot of work to recopy writing done with pencil and paper.

3. **Mechanics.** There are many mechanical aspects of writing, such as correct spelling and grammar, readability, length, and so on. Computer programs have been written that can help find spelling and grammar errors. Computer programs can count the number of words in your writing. Computer programs can test readability level.

4. **Publication.** Probably you have heard of the idea of **desktop publishing**. In recent years, better and better computer printers have been developed. Computer software has been developed to take advantage of these printers. Now, many newspapers, magazines, and books are published directly from computer printouts. This is called desktop.publishing.

   It is easy to learn to do desktop publishing. Many schools use desktop publishing to do their school newspapers. Some use desktop publishing to do their yearbooks.

5. **Making use of your previous writings.** With a word processor, you can save your writings on a computer disk. Days, weeks, or months later you may find that some of your old writings are useful in doing a new project. A computer makes it very easy to "cut and paste" pieces from old writings into new writings. It makes it easy to build on your previous writing work.

Begin ✍✍ (You may want to write in your journal.)

Think about the courses you are taking in school. For each course, think about how a word processor is useful. Order your courses on the basis of how useful a word processor is. The first course on your list should be the one in which a word processor is most useful.

Do you use a word processor in all of your courses? If the answer is no, discuss why not.

End ✍✍

Database

A **database** is an organized collection of data. If the data are stored in a computer, it is called a computer database. A computer database has all of the features F1-F4 discussed previously in this chapter.

There are many different kinds of databases that can be stored in a computer. Three types of databases are discussed below. Sometimes these different types overlap. That is, one database may contain features of two or more of the categories listed below.

1. Table database. The data are organized into rows and columns. Here is a small example.

Name	Street Address	City	State
Joan Adams	9884 Smith St.	New York	NY
Paul Jones	6824 South Plum St.	Columbus	OH
Tom Charles	2223 East Lake Road	Denver	CO
Sue Walden	221 Pine Blvd.	Houston	TX
Pat Smith	23232 Jackson St.	Los Angeles	CA

   Each row in the table is one record of information. Each record is divided into fields. The small table database given above consists of five records, and each record contains four fields. A large table database might contain many thousands of records and each record might contain dozens of fields.

2. Reference database. This is a database of references. It contains the author, title, publication data, a brief list of topics covered, and perhaps a brief summary. Here is one sample entry of a reference database.

   Citation: Moursund, David G. (1993). *Problem-Solving Models for Computer Literacy.* International Society for Technology in Education, Eugene, Oregon.

   Descriptors: computer, computer applications, computer literacy, computer modeling, computer programming, higher-order thinking skills, journaling, metacognition, modeling, problem solving, thinking.

   Abstract: A secondary school book on roles of computers in problem solving. Covers basic ideas of problem solving in general and problem solving using computers. Intended for use in a computer literacy course but can also be used in other courses. No specific

knowledge of computers or of mathematics is assumed. The problem-solving ideas cut across all fields of study. The book stresses metacognition and has students do a lot of writing in a journal.

3. Full-text database. As the capacity of computer storage devices has grown, it has become possible to store entire books (including pictures and diagrams) in a computer. Many schools now have an encyclopedia stored on a computer disk. Many reference databases contain the entire texts of articles.

One of the most important ideas in problem solving is building on the work that other people have done. But often it is quite difficult to gain access to this work. Even if people have written about their work and published articles on it, it is often hard to find the references.

Computer databases have made a big difference in helping people build on the work of others. Here are a few major ways in which computer databases help in problem solving.

1. **Sharing of current data.** There are many databases that need to be changed frequently. For example, consider the table database of seats on airplane flights. There are thousands of ticket agents who sell tickets. When a ticket is sold, the database needs to be changed.

   Similarly, consider a reference database. There are many thousands of magazine and journal articles published each week. Reference databases need to be updated frequently.

   Many grocery stores now keep their complete price lists in a computer table database. This makes it easy to change prices. There is a computer terminal at the checkout counter. A bar code scanner reads the product number from a label on a grocery item. The computer then looks up the item in its database. It displays the item name and price on the checkout display and keeps a running total of the bill.

2. **Convenience of access.** Many computer databases can be accessed by using a computer hooked to a telephone line. This means that the information comes to you rather than you going to where the information is stored.

3. **Quick access.** Computer databases can be searched very quickly. The computer does most of the work for you.

4. **Reorganizing data.** A computer can be used to reorganize a computer database. For example, a table database can be ordered alphabetically based on the entries in a particular field. In the name and address table database given above, a computer could quickly put the records in ZIP code order.

5. **Low cost**. In many cases it is much cheaper to make use of a computer database than it would be to obtain the same information by noncomputer means. For example, suppose you are doing a school report and you need to read a particular article. Suppose the article is not in your school library or any library in your town. If the article is in a full-text computer database, you can quickly gain access to it. This may be cheaper than your school subscribing to all of the magazines students might need to read.

Begin ✍✍ (You may want to write in your journal.)

Think about the courses you are taking in school. For each course, think about how useful computer databases might be. Order your courses on the basis of usefulness of computer databases. The first course on your list should be the one in which computer databases are most useful.

If computer databases are not used in your courses, think about why. How would computer databases change some of your courses?

End ✍✍

Graphics

Recall the quote "A picture is worth a thousand words." It has long been recognized that pictures can be more effective than words in describing a scene. A picture is often a very good model.

Computers are very useful for storing and working with pictures, drawings, diagrams, and math graphs. **Computer graphics** have all of the features F1-F4 discussed earlier in this chapter.

Here are three general types of computer graphics applications.

1. Math graphics. One example is the graphing of data by using a bar graph, circle graph, or line graph. Another example is the graphing of math equations.

2. Engineering graphics. This covers a wide range of areas, such as architectural drawings for a building and drawings of a part to be manufactured in a factory.

3. Artistic graphics. This covers a wide variety of applications. Examples range from using a computer to produce nicely lettered signs to producing animated movies.

Computer graphics has opened up a whole new approach to problem solving. It is easy to use a computer to create pictures. The pictures may be in full color and they may even be motion pictures. (Take a look at the "credit" lines the next time you watch the evening news or go to a *Star Trek* movie.)

Computer graphics are particularly useful in problems with the following characteristics.

1. **Changeability.** Imagine you are designing a cover page for a report. The cover page will contain pictures and lettering. This is easy to do on a computer but hard to do by hand. When you are doing it on a computer, it is very easy to correct mistakes. You can look at what you have produced and decide if you like it. If you don't like some parts, it is easy to change them.

2. **Pictorial representations of data.** The human mind is not good at dealing with a large table of data. For example, think about a table of data giving the population density for each state in the country. It would be hard to see patterns and to answer questions about where there are high or low population densities. But a computer could easily represent this data as a map of the country. It could use different colors to represent different population densities. Then you could tell at a glance the regions of high or low population density.

3. **Color and motion.** The computer field and the television field are beginning to merge. You can use a computer to do animation. Video pictures and sound tracks can be stored in a computer system. These can be combined with your drawings and writing. The result is called **hypertext**. It is a new form of "writing" that did not exist before computers.

Begin ✍✍ (You may want to write in your journal.)

Think about the courses you are taking in school. For each course, think about how computer graphics could be useful. Order your courses on the basis of usefulness of computer graphics. The first course on your list should be the one in which computer graphics are most useful.

If computer graphics are not used in your courses, discuss why. How would your courses be better if computer graphics were used?

End ✍✍

Spreadsheet

Perhaps you have seen the type of paper that accountants use to keep detailed business records. The paper is ruled into rows and columns to make a large number of little boxes, or "cells." Each cell can hold a number, a few words, or a formula.

A **spreadsheet** is merely a computerized accounting sheet. A spreadsheet has all of the features F1-F4 discussed previously in this chapter. You can enter words and numbers into the cells on the page. In addition, you can write formulas that tell a computer what to do with the numbers.

For example, look at the little piece of a grade book given below. It is a spreadsheet model (a computer model) of a gradebook. The teacher has given three assignments and one quiz. The teacher enters the student names and scores into the spreadsheet. The spreadsheet calculates the student total scores as well as the averages. It does this by using simple formulas the teacher has placed in the spreadsheet program.

Suppose the teacher finds an error in a student's score. It is easy to correct the error. The teacher types in the correct number. The computer does all of the rest of the work. It recalculates all of the totals and averages.

Student Name	Assign. # 1	Assign. # 2	Assign. #3	Quiz # 1	Total
	(10 possible)	(5 possible)	(10 possible)	(30 possible)	
Adams, Ruth	8	4	9	22	43
Best, Bob	5	5	10	19	39
Dowden, Terry	10	3	10	28	51
Gold, Sam	9	5	8	26	48
Lansing, Paul	9	5	7	20	41
Perez, Pat	10	4	9	25	48
Average	8.50	4.33	8.83	23.33	45.00

A spreadsheet is useful whenever one is working with a table of numbers that are to be connected by formulas. This is common in business, and it often occurs in science, math, and social studies. Thus, a spreadsheet is a rather general purpose aid to problem solving. It can be used to model many different kinds of problems.

It is easy to learn how to do a few simple things with a spreadsheet. However, a spreadsheet is a very complex tool. Many high schools and colleges offer entire courses on how to use a spreadsheet.

Begin ✍✍ (You may want to write in your journal.)

Think about the courses you are taking in school. For each course, think about how a spreadsheet might be useful. Order your courses on the basis of how useful a spreadsheet might be. The first course on your list should be the one in which a spreadsheet is most useful.

If spreadsheets are not used in your courses, discuss why. How might your courses be better if they helped you to learn to develop and use spreadsheet models?

End ✍✍

Networking Computers

This section discusses the idea of hooking computers together. If the computers are located close together, this can be done by direct wiring. If

the computers are a long distance apart, they may be hooked together through use of the telephone system. The computers that are hooked together are called a **computer network** or a **network**.

People using a computer network may communicate with each other or with information stored in each machine. There are three major uses of computer networks:

1. Communication among people. This can occur in several forms. In **electronic mail (E-mail)** one computer user sends a message to another computer user. The message is private, and other people using the computer network are not allowed to read the message.

   In an electronic bulletin board, messages are "posted" so that all users of the system can read them. It is almost like a school bulletin board, but only users of the computer system can read the messages.

2. Accessing databases. This idea was discussed earlier in this chapter.

3. Sharing computer resources. A computer network might have just one printer or perhaps just one hard disk. All users of the network can make use of the printer or hard disk. In another type of application, there may be a centrally located, very powerful super computer. Users of the system can have the centrally located computer carry out massive computations that would take far too long on their own local computers.

Begin ✍✍ (You may want to write in your journal.)

Think about the courses you are taking in school. For each course, think about how computer networking would be useful. Order your courses on the basis of how useful computer networking would be. The first course on your list should be the one in which computer networking is most useful.

If computer networks are not used in your courses, discuss why. How would your courses be better if you were using networking in them?

End ✍✍

CHAPTER 9 SUMMARY

Some computer software is designed to help solve a wide range of problems. This software can be used to build computer models for many different problems.

Key features of good, general purpose software include the following:

F1. The software is useful in helping to solve many different kinds of problems from many different fields.

F2. The software is useful in working on the kinds of problems in which one needs to make many changes.

F3. The software takes advantage of the storage and processing power of a computer to do quite a bit of work for you.

F4. The software is user friendly.

Activities

1. Pick some idea you thought about while reading this chapter. Perhaps you thought about how some piece of computer software helped you to solve a problem. Perhaps you thought about some general purpose computer software that was not discussed in this chapter. Perhaps you thought about how it would be fun to use some of the general purpose pieces of software in other classes you are taking. Write several paragraphs in your journal about some idea you thought about. You might want to use the outline given below.

    1. Make a title for this journal entry. Your title might look like this:

    CHAPTER 9 ACTIVITY 1
    AN IDEA I HAD WHILE I WAS READING CHAPTER 9

    2. Write down and explain the idea.

    3. Explain why the idea interests you. Why did you remember this idea?

4. How does this idea relate to things you do outside of this class?

5. What else do you think about when you think about this idea?

2. Get together with two or three other students in the class. Each of you is to select one idea from this chapter that seems particularly important to you. Each of you is to spend a minute or two talking about the topic. Why did you select it? Why is it important to you? What difference does it make in your life?

   In talking about your topic, try to make use of some of the new terms introduced in this chapter. A list is given below. Remember, definitions are given in the Glossary.

   computer network (network)
   database
   desktop publishing
   electronic mail (E-mail)
   graphics (computer graphics)
   human-machine interface
   hypertext
   spreadsheet
   user friendly

3. Make up a short quiz of lower-order thinking skill questions for this chapter. (Include correct answers. Often a lower-order skill question has only one correct answer.) Your quiz should consist of questions that can be answered by a person who has a low level of knowledge of the material in this chapter.

   Then try out your quiz on two students in your class.

4. Make up a short quiz of higher-order thinking skill questions for this chapter. (Think about possible correct answers. Remember that a good higher-order skill question is likely to have many different correct answers.) Your quiz should consist of questions that can be answered by a person who has a good understanding of the material and ideas in this chapter.

   Then try out your quiz on two students in your class.

5. Think about using a word processor to do a hard multiplication or division problem. (This is like doing arithmetic on a typewriter.) For

example, think about using it to do 973 x 729 or perhaps 683073 ÷ 729. Then actually try doing these computations using a word processor. Write a brief discussion of your conclusions.

6. Select a general purpose software tool you have not used before. Learn to use it. As you are learning, think about how you are learning. Keep detailed notes in your journal. Write about "learning to learn."

7. Some of the basics of education are reading, writing, arithmetic, speaking, and listening. The most widely used general purpose computer application packages are database, graphics, networking, spreadsheet, and word processing. Compare and contrast these two lists. How are they the same and how are they different? Use this comparison to predict some new general purpose computer applications that may be developed in the future.

8. Many science fiction stories involve a "voice writer." It is a word processor you can talk to. Suppose that young children had a voice writer as they were learning to read and write. How do you think this would change learning to read and write?

Chapter 10
Computer Systems

ORGANIZE YOUR THINKING

A computer system consists of hardware and software. Hardware is physical machinery. Software is computer programs.

The computer field is changing quite rapidly. Each year, computer systems improve quite a bit. Both the hardware and the software get better.

To use a computer, you must communicate with the machine. You must tell it what to do, using a language that the computer "understands." Modern computers are much easier to use than older computers because it is easier to tell them what to do. Rapid progress in continuing in this area.

Introduction

Some people think of a computer as a mysterious "**black box**" whose internal design and workings are unfathomable. With this approach, you have little or no knowledge of what goes on inside the black box. You tell it to do things, and it does them. If something goes wrong, you ask other people for help.

However, most people like to have an understanding of what goes on inside the machines they use. It is fun to understand the internal workings of machines and the history of their development. Also, it will help you to make better use of the machine. This chapter will increase your understanding of how a computer actually works.

Begin ✍✍ (You may want to write in your journal.)

Are the internal workings of a car a "black box" for you? How about an electric motor? A light bulb? Think about the idea of a black box. How does it feel to use devices you do not understand? How does it feel to use

devices you do understand? What do you do when a black box doesn't work as expected?

End ✍✍

What Can a Computer Do?

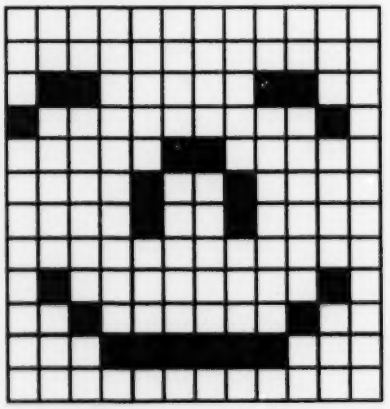
A **computer system** consists of **hardware** (physical machinery) and **software** (computer programs). Basically, a computer is a rather simple machine. It can only do very simple things. However, it does these simple things rapidly and accurately. Here are the main things a computer can do.

1. A computer can work with letters, digits, punctuation marks, and other symbols.

   A keyboard containing these symbols is used to "talk to" a computer. You know how to read and write using the same symbols computers use. This helps you in learning to use a computer.

2. A computer can work with pictures and sound.

   Think of a picture as being made up of small dots or small squares. These are called **pixels** (picture elements). A computer can store a picture as a set of numbers. Each number gives the color of one pixel in the picture.



A picture, 12 by 12 pixels.

One way to store sound in a computer is to break it into many short segments. The frequency of each segment is measured, and the computer stores the numbers that represent these frequencies. This same idea is used to store music on compact discs.

3. A computer can do some simple operations, such as adding two numbers and comparing two numbers to see which is larger.

   Every computer contains at least one **central processing unit** (CPU). The CPU carries out simple tasks, such as adding a pair of numbers or checking to see if a number is negative.

4. A computer's memory can store a computer program—a detailed, step-by-step set of directions. A program tells a computer's CPU what to do to solve some problem.

   The key idea is that a computer's memory can store both the data you want to process and the program telling how to process the data. Both the data and the program can easily be changed to help solve different problems.

5. A computer can carry out the steps in a computer program very rapidly and very accurately.

   A modern computer can carry out millions of individual operations in one second. It can function for many days without a single malfunction.

Hardware: A Very Brief History

The history of computer hardware is a history of change. Until about 50 years ago, the rate of change was slow. The first general purpose electronic digital computer was completed in 1945. Since then, change has been rapid. One reason for studying the history of computer hardware is to understand how this rapid rate of change affects you.

The history of computer hardware is a story of people seeking ways to make it easier to do arithmetic. The abacus, invented about 5,000 years ago, can be thought of as a distant relative of the modern computer. It many countries it is still used today.

More than 300 years ago people began to build mechanical calculators that could add, subtract, multiply, and divide. The arithmetic was done by a collection of gears.

During the 1800s, people got the idea of building calculators that could automatically follow a sequence of instructions. As with mechanical calculators, these were machines containing very large numbers of gears and other moving parts. However, such machines proved to be very difficult to build with the necessary level of precision. By the late 1800s, however, quite useful data-processing machines were being built and used. Perhaps the most famous was the punch-card processing equipment developed by Herman Hollerith for use in processing the 1890 census data for the United States.

During the 1930s, people got the idea of using electrical and electronic parts to build automatic calculating machines. This eventually led to the development of the electronic digital computer. During the early 1940s, rapid progress in building such computers occurred in Germany, Great Britain, and the United States.

After these first electronic digital computers were developed, people realized they could be used to do more than just simple arithmetic. Computers could work with words and pictures. Computers could carry out tasks that previously had seemed to require human intelligence. The field of computer science was born!

During the 1950s, the computer industry developed. Many different companies built and sold computers. Computers began to become common in business, government, and higher education.

But all of the early computers used vacuum tubes. A vacuum tube uses a lot of electrical power. These tubes produce quite a bit of heat. Also, vacuum tubes are somewhat like electrical light bulbs—they burn out frequently. The early computers contained many thousands of vacuum tubes. They required lots of electrical power and very good air-conditioning. They were not very reliable because tubes burnt out so often.

The invention of the transistor changed all of this. A transistor can do many of the same things a vacuum tube can do. It is much smaller than a vacuum tube and it doesn't burn out as quickly. It uses very little electrical power. The first computers that used transistors were built in the late 1950s.

Transistor technology has progressed at a very rapid pace. People discovered how to build an **integrated circuit** that contains a large number of transistors and other electronic parts. An integrated circuit is sometimes

called a **chip** because a small piece of silicone (a "chip" of silicone) is used in the manufacturing process. A chip is about the size of your fingernail.

Now, a single integrated circuit may be equivalent to a million vacuum tubes and yet cost little more than one vacuum tube. This progress has made it possible to have very cheap hand-held calculators, portable computers, and computers in schools. Computers are cheap enough so that millions of people have them in their homes.

Roughly speaking, the development of computer hardware has progressed by a factor of one million during the past 40 years. This means, for example, that the cost of a given amount of computation has decreased by a factor of about a million during that time. Computer hardware will continue to improve very rapidly for the next few decades.

This progress will affect you. Twenty years from now people will look back at the computers now being used in schools. They will laugh at these primitive "toys." However, the basic ideas on using a computer to help solve problems will not have changed very much. If you learn how to use computers to help you solve problems, the underlying ideas will last a lifetime!

Begin ✍✍ (Please write in your journal.)

1. Make a title for this journal entry. Your title might look like this:

RAPID CHANGE

2. Make a list of some things that seem to change very rapidly. Your list might include "popular" television programs, your younger brother or sister, medicine, and consumer products.

3. For each item on your list, briefly discuss how the changes affect your life.

End ✍✍

Computer Software: A Step-by-Step Set of Directions

A computer program is a set of directions telling a computer what to do. If the task is quite simple, the computer program may be quite simple. However, if the task is complex, the computer program may be very complex. Some computer programs contain millions of instructions. Teams of programmers may work for years on some programming projects.

Let's try a little experiment. Pick up a pen or pencil. Draw a small circle. Then draw a smaller circle inside of the circle. Put down the pen or pencil.

You have just carried out a step-by-step set of directions. Unless you have a disability that makes the operations difficult or impossible, it was easy for you to understand and follow the directions.

However, when you were very young, you couldn't have followed this set of directions. You didn't know the meaning of the words in the set of directions. It took you a long time to train your body to be able to do things like pick up a pencil or draw a circle. These are actually quite complex operations. Your mind and body can do them automatically now only because you learned through a great deal of practice.

Now think about picking up your pencil, going to the pencil sharpener, sharpening your pencil, and returning to your seat. Please do the following writing exercise.

Begin ✍✍ (Please write in your journal.)

1. Make a title for this journal entry. Your title might look like this:

TO SHARPEN A PENCIL

2. Write a detailed, step-by-step set of directions for the process of sharpening your pencil.

3. Then examine each of the steps to see how hard it is to do. List the two easiest steps and explain why they are easy. List the two hardest steps and explain why they are hard.

4. Did your set of directions take into consideration that the lead might break while you are sharpening your pencil? If not, add this to your directions.

5. Did your set of directions take into consideration that your pencil might become too short to sharpen? Make a list of several "flaws" in your set of directions.

End ✍✍

In the above journal-writing activity you wrote down a **procedure** for sharpening a pencil. A procedure is a step-by-step set of directions for accomplishing some task or solving a problem. **Procedural thinking** is the type of thinking needed to develop and/or use procedures to help solve a problem.

A procedure is designed to be carried out in a mechanical, nonthinking fashion by someone or some thing, such as a machine. A computer is a machine designed to carry out certain types of procedures. These procedures are called computer programs and must be written in a form that a computer can "understand."

Programming Languages

A set of directions tells someone or some thing (an agent) what to do. A set of directions must take into consideration the capabilities of the agent that will carry out the directions. If the agent is very "smart," the directions can be quite simple. For example, you can say "Walk to the pencil sharpener" to a person. The person will avoid stepping on people and walking over desks and chairs.

You can think of a robot as a computer with a television camera for an eye and with mechanical arms and legs. How do you tell a robot to sharpen a pencil? How can the robot know when it is sharp enough? How do you tell a robot not to step on people? These are very hard questions. Programmers who work with robots have a hard time figuring out answers to these kinds of questions.

A computer is designed to be able to carry out certain types of instructions. You can think of each of these as a primitive, a very simple

problem that the computer can solve. A computer is built to be able to follow instructions written in a language consisting of these primitives. This is called a **machine language**. A machine-language program is a set of instructions telling a computer which primitive operations to perform.

Computers are not all alike. Different brands or different models of computers may have different sets of primitives built into them. That is, they have different machine languages. A computer program written in the machine language of one machine may not be useable on a different machine.

Another difficulty is that the machine-language steps that a computer can carry out are very simple relative to the tasks that people want accomplished. Think about how many different steps it takes to look up a word in a dictionary. A machine-language program to do this consists of a large list of instructions. The smallest error in this set of instructions will lead to the computer making errors.

Most people are not good at writing detailed instructions that contain no errors. Computer programmers call a programming error a **bug**. It is difficult to write error-free programs. It also difficult to detect and correct errors in a computer program (to **debug** a program). A computer programmer must be skilled at detecting and correcting bugs.

Thus, early computer scientists put a lot of thought into how to help people write computer programs. They developed the idea of a programming language that was more like human "natural" language than a machine language. The idea was to develop a language so that a computer could translate from it into machine language. This is called a **higher-level programming language**

One of the very early higher-level programming languages was called Fortran. It was completed in 1957 and was designed to be used by scientists and engineers. It is still widely used today. One reason for this is that billions of dollars have been spent in writing Fortran programs. These programs are still useful. They are a way that people build on previous work of other people.

In the mid-1960s, a higher-level programming language called BASIC was developed to be used by college students. It is now widely used by younger students and by many other people.

Many other languages were developed to meet the needs of different people. For example, COBOL was designed for use in business. It is still widely used because many billions of dollars have been spent writing COBOL programs.

Logo was designed to fit the needs of elementary school students. It is now used at all grade levels and even in some colleges.

Begin ✍✍ (You may want to write in your journal.)

A computer program can translate a BASIC program or a Logo program into machine language. Can a computer program translate Russian into English? In what sense are these translation problems alike? How are they different?

End ✍✍

Sample Computer Programs

Here are three very simple programs written in BASIC. The first directs the computer to ask the name of the person using the program. The computer then prints out the word HELLO, followed by the name. The second asks the user to type in two numbers. The computer then finds the sum of the two numbers and prints it out. The third program prints out the integers from 1 to 150.

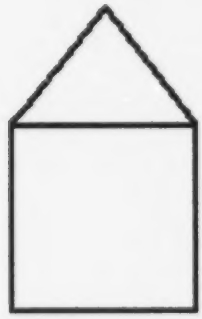
In these three examples, each line of the BASIC program has a line number. These simple programs have line numbers incremented in steps of 10. The early versions of BASIC used line numbers to help the programmer make changes to different lines in the program, to insert new lines, and to allow a statement in one line to refer to a statement in a different line. More modern versions of BASIC do not make use of line numbers.

```
10 PRINT "WHAT IS YOUR NAME?"
20 INPUT N$
30 PRINT "HELLO "; N$
40 END
```

```
10 PRINT "THIS PROGRAM ADDS TWO NUMBERS."
20 PRINT "PLEASE TYPE IN THE FIRST NUMBER."
30 INPUT A
40 PRINT "PLEASE TYPE IN THE SECOND NUMBER."
50 INPUT B
60 LET C = A + B
70 PRINT "THE SUM OF THE TWO NUMBERS IS "; C
80 END
```

```
10 LET N = 1
20 PRINT N
30 LET N = N + 1
40 IF N <= 150 THEN 20
50 END
```

Next, we give a simple Logo program. It directs the computer to draw a simple picture. The picture is a "house" made up of a triangle sitting on top of a square.



This program makes use of a number of parts, called procedures. This program consists of a main procedure and four subprocedures. The main procedure is called HOUSE and the four subprocedures are called SQUARE, TRIANGLE, MOVE.TO.ROOF, and MOVE.TO.START. Logo is a programming language that is especially useful in teaching procedural thinking.

```
TO HOUSE
SQUARE 50
MOVE.TO.ROOF 50
TRIANGLE 50
MOVE.TO.START 50
END

TO SQUARE :SIZE
REPEAT 4 [FORWARD :SIZE RIGHT 90]
END

TO TRIANGLE :SIZE
REPEAT 3[FORWARD :SIZE RIGHT 120]
END

TO MOVE.TO.ROOF :LENGTH
FORWARD :LENGTH
RIGHT 30
END

TO MOVE.TO.START :DISTANCE
LEFT 30
BACK :DISTANCE
END
```

Hundreds of higher-level programming languages have been developed. All have certain features in common:

1. Each was designed to fit the needs of programmers working on specific types of problems. A language for solving business problems may not be very good for solving science problems. A language for grade school students may not be good for college students.

2. Each can be used on a variety of makes and models of computers. When a new type of computer is produced, people write translating programs for each language that is to be used on the new computer.

   For example, suppose a manufacturer wants a new computer to use BASIC, COBOL, and Logo. Then three translating programs need to be written. One must translate BASIC statements into the machine language of the new computer. The second must translate COBOL statements and the third must translate Logo statements.

Making Computers Easier to Use

Higher-level programming languages make it easier for people to write programs. The computer can do quite a bit of the work. This is an

interesting idea. Are there other ways a computer can help a person to use a computer?

The answer is yes. Many researchers work on making computers easier to use. They have made a great deal of progress. At one time it was thought that most people needed to learn how to write computer programs if they wanted to use computers. Now this is definitely incorrect! Most people who use computers know little about computer programming.

Instead, most computer users make use of application packages. These are designed to be easy to learn how to use. A modern word-processing program is a very sophisticated piece of software. The program may be tens of thousands of lines long. However, it takes only a few minutes to learn to do some very useful things with a word processor.

Similar statements hold for other applications, such as database, graphics, and spreadsheet. Each of these application packages is as complicated as a higher-level programming language. However, each is designed to help transfer of learning from the user's previous knowledge. A person who knows how to read and write can easily learn to use a word processor. A person who knows accounting can easily learn to use a spreadsheet.

However, each major application package is designed for working on only certain types of problems. You wouldn't want to use a word processor to try to solve spreadsheet or database problems! Also, the ease of use in solving simple problems is misleading. For example, the instruction manual for the word processor may be hundreds of pages long. It takes hundreds of hours of study and practice to master all of the features of a modern word processor. Similar statements hold for the other major computer applications.

There is still one more level of complexity. A modern application package may contain a built-in programming language. A database system provides an excellent example. A modern database application package includes a programming language designed to help solve database problems. You can easily learn to use the database software at a simple level to solve simple problems. This may take only a few hours of effort. However, it may take hundreds of hours of study and practice to fully master such a piece of software.

Some Thoughts on Being a Computer Programmer

Every student can learn to write simple computer programs to solve simple problems. Millions of grade school students have learned to write simple programs in Logo. Millions of secondary school students have learned to write simple programs in BASIC or Logo. Nowadays, almost all college students in science and engineering learn to write computer programs. They write programs to solve the kinds of problems that come up in the courses they are taking.

However, application packages are getting better and better. More of these packages are being developed. This means that for any particular area of study, there is probably software designed just for people in that field. At a beginner's level, it is almost always easier to learn to use the software than to learn a general purpose programming language. You can quickly learn to use the application package to solve a variety of simple problems.

However, as you attempt to solve more difficult problems you will find that it takes a great deal of study and practice. The task is much like learning a general purpose higher-level programming language.

This leads to two questions. Who should learn to write computer programs? Who should seek a career as a computer programmer? The following ideas may help you answer these questions for yourself.

1. You can learn to write simple programs in a language such as BASIC or Logo. This can be a very useful part of your education. The goal isn't really to learn the programming language. Rather, the goal is to learn about learning a programming language. Learn what is involved in solving problems by writing programs. Gain skill in procedural thinking. You want to learn how your mind works as it deals with these tasks.

2. In many fields, such as business, engineering, and science, it is very useful to be able to write programs. If you intend to go to college and major in one of these areas, you will likely benefit by learning to write computer programs.

3. A professional computer programmer is a person who has a combination of skills. These include:

   A. The ability to master several general purpose programming languages as well as a number of complex application packages.

B. The ability to write programs that help to solve the types of problems in a particular area. A programmer gets hired to help solve certain types of problems, such as business problems or science problems. To solve the problems in a particular area, you need to know a lot about that area.

C. Good skills in communicating with the people who need to have programs written. Generally, this means that you need to have good oral and written communication skills.

D. The ability to rapidly learn about new computer hardware and new computer software. The computer field will continue to change very rapidly for many years to come.

E. Good problem-solving skills, patience, persistence, and the willingness to work hard.

A computer is an aid to problem solving. A computer programmer tells a computer how to solve problems. Computer programming requires a high level of precision in communication. A computer does exactly what it is told to do. The smallest error on the part of the programmer can lead to a computer producing wrong answers to a problem.

Some people enjoy working in an area that requires very precise thinking and very precise communication. They have considerable ability to do procedural thinking and to develop procedures to solve problems. Other people do not like this environment. One reason for learning some computer programming is to learn more about yourself. Learning more about yourself is certainly one of the ultimate goals in education.

CHAPTER 10 SUMMARY

Each year sees continued rapid progress in computer hardware and software. This progress is occurring in three areas:

1. Development of hardware that is faster, more reliable, and cheaper.

2. Development of software that is easier to learn how to use and easier to use.

3. Development of software application packages that can solve or help solve the problems in a particular discipline.

Activities

1. Pick some idea you thought about while reading this chapter. Perhaps you thought about how your mind is like a computer and how school is "programming" your mind. Perhaps you thought about how some subjects seem to involve many detailed, step-by-step sets of directions that you have to learn, while other subjects involve very few. Write several paragraphs in your journal on some idea you thought about. You might want to use the outline given below.

    1. Make a title for this journal entry. Your title might look like this:

    CHAPTER 10 ACTIVITY 1
    AN IDEA I HAD WHILE I WAS READING CHAPTER 10

    2. Write down and explain the idea.

    3. Explain why the idea interests you. Why did you remember this idea?

    4. How does this idea relate to things you do outside of this class?

    5. What else do you think about when you think about this idea?

2. Get together with two or three other students in the class. Each of you is to select one idea from this chapter that seems particularly important to you. Each of you is to spend a minute or two talking about the topic.

Why did you select it? Why is it important to you? What difference does it make in your life?

In talking about your topic, try to make use of some of the new terms introduced in this chapter. A list is given below. Remember, definitions are given in the Glossary.

black box
bug
central processing unit (CPU)
chip
computer system
debug
hardware
higher-level programming language
integrated circuit
machine language
procedure
procedural thinking
software

3. Make up a short quiz of lower-order thinking skill questions for this chapter. (Include correct answers. Often a lower-order skill question has only one correct answer.) Your quiz should consist of questions that can be answered by a person who has a low level of knowledge of the material in this chapter.

   Then try out your quiz on two students in your class.

4. Make up a short quiz of higher-order thinking skill questions for this chapter. (Think about some possible correct answers. Remember that a good higher-order skill question is likely to have many different correct answers.) Your quiz should consist of questions that can be answered by a person who has a good understanding of the material and ideas in this chapter.

   Then try out your quiz on two students in your class.

5. In what ways is communicating with a computer like talking with a person? In what ways is it different? Do you think a person with good skills in talking with other people will be a good computer programmer? Why?

6. Do you know how to write computer programs? If the answer is yes, do some metacognition on the learning process. Did you enjoy learning to write programs? Was it hard to learn? Would you like to learn more about programming?

7. Write arguments for both sides of the question "Should all students learn how to write computer programs?" Then summarize by giving your personal opinion.

8. This book raises the question "If a computer can solve or help solve a type of problem that students study in school, what should students learn about solving this type of problem?" Write an essay on this question.

9. What do you feel are the three most important ideas in this book?

Glossary

One of the major goals of this book is to help you learn some new words so you can talk and write about problem solving. Being able to talk and write about a problem is a big help in working to solve the problem. Thus, you should place considerable emphasis on learning to use the terms contained in the Glossary in your talking and writing.

The number in parentheses after a term is the chapter in which the term is first defined. In some cases, a term is used earlier in the book without being defined. In a few other cases, a term is used without being defined.

Advance organizer (1): A brief introduction to a lesson or a chapter. It contains a few of the key ideas that will be covered in the material. Its purpose is to get your mind started thinking on the new ideas. Before you start to study new material, think about some of the things you already know about the material.

Algorithm: A step-by-step set of directions that tells how to solve a particular kind of problem. It is guaranteed to solve the problem, provided that no errors occur in following the directions. Math courses teach algorithms for multiplication, division, calculating square root, and solving other computational problems. A cook's recipe is a type of algorithm.

Basic skills (1): Skills that can be used to help understand and solve a wide range of problems. Educators suggest that reading, writing, arithmetic, speaking, and listening are basic skills. They want all students to gain these skills.

Black box (10): A term used to describe a machine, especially a computer, whose internal working seems mysterious and unknowable to the describer.

Bottom-up strategy (5): A strategy for problem solving that involves starting with smaller and simpler problems that you know how to solve. These are called primitives. The strategy may be goal directed, so

primitives are put together with a specific goal in mind. But the strategy may also be used in a rather random and creative fashion, with no particular goal in mind. A goal may later be selected based on observing the outcome of accomplishing a number of initial tasks. Computer programmers make use of both bottom-up and top-down strategies in problem solving.

Brain: Your brain contains many billions of neurons. The neurons store information and process information. When your brain is "thinking," it may be using a huge number of different neurons.

Brainstorming (3): A strategy useful in understanding a problem situation and in getting ideas on ways to solve a problem. One or more people generate ideas "off the top of their heads," quickly and without comment about the quality of the ideas.

Bug (10): An error or a mistake. A bug may be an error in the design of a plan on how to solve a problem. It may be a mistake in details of the implementation of a procedure to carry out a plan. A hardware bug refers to circuitry that is not working right. A software bug is an error in a computer program.

Calculator primitive (5): The functions built into a calculator, such as addition and division. A primitive you have because the solution process is built into a calculator and you have access to the calculator.

Central Processing Unit (CPU) (10): The part of computer circuitry that actually carries out the instructions given in a computer program. Some computers contain only one CPU. Others contain a large number of CPUs, and many of them may be engaged simultaneously working on a single problem. This parallel processing is somewhat akin to how the neurons in a human brain function.

Chip (10): See **integrated circuit**.

Clearly defined problem (3)**:** A problem in which the givens, goal, and resources and restrictions are all clearly specified.

Cognition: Thinking.

Computer graphics (9): Use of a computer to store, manipulate, and display pictures, diagrams, and other graphic images.

Computer model (8): A model for a problem that is stored in a computer in a form that the computer can use to carry out computations and other activities needed to make use of the model. A computer can store and work with written material, pictures, and sound.

Computer network (9): A collection of computers and other computer facilities connected together to allow electronic communication among them.

Computer primitive (5): A primitive that you have because you have a computer program that can carry out the process of solving a particular problem as well as access to a computer that can run the program.

Computer program (3): See **software**.

Computer symbolic model (8): See **computer model**.

Computer system (10): A combination of computer hardware and software that works together. See **hardware** and **software**.

Conscious short-term memory: See **short-term memory**.

Constructivism: A view of learning in which knowledge is something that the individual learners must construct for and by themselves. What you learn is highly dependent on what you already know, and this varies from individual to individual.

Cooperative learning (3)**:** An approach to learning in which small groups of students (usually three or four) work together. Students help each other to learn. They have both shared and individual responsibility for learning.

CPU: See **central processing unit**.

Database (9): An organized collection of data. A computer is very useful for creating and storing databases. A computer is very useful in manipulating the data in a database to help solve a problem.

Debug (10): To remove bugs from an overall process for solving a problem. In the computer field, the term is most often used to refer to detecting and fixing errors in a computer program.

Desktop publishing (9): The use of a computer system for word processing, page layout, and/or printing in the overall process of publishing.

Domain-specific knowledge: The detailed knowledge of a particular field of study. Each field of study has accumulated a great deal of knowledge. One can think of a field of study as being defined by the types of problems it works to solve, the techniques it has developed, its vocabulary and notation, and so on. Research suggests that it is necessary to have considerable domain-specific knowledge to solve the problems in a domain.

Electronic mail; E-mail (9): Mail messages sent via computer network. Any data that can be stored in a computer can be sent to another computer via electronic mail.

Far transfer situation (7): When one problem situation seems so different from another problem situation that you do not readily transfer the knowledge and skills that will help deal with one of the problem situations to the other problem situation. Contrast this with **near transfer situation.**

Formal problem: Vocabulary used to emphasize that the problem has the following four components: given initial situation, goal, resources, ownership. Careful attention has been paid to ensuring all are present and clearly defined.

Four-step plan for solving a problem (4): See **four-step strategy for solving a problem.**

Four-step strategy for solving a problem (4): A strategy consisting of these four steps:

1. Understand the problem.
2. Devise a plan of action.
3. Carry out the plan of action.
4. Examine the results. Has the problem been solved, and have new problems have been created?

This particular strategy is useful in attempting to solve almost any problem. However, using it does not guarantee that you will succeed in solving the problem. See **strategy.**

Given initial situation (3): One of the four components of a problem. It is the initial state, the way things are to begin with.

Givens; given situation (3): See **given initial situation**.

Goal (3): One of the four components of a problem. It is the desired final state, the target, what one would like to reach.

Graphics (9): See **computer graphics**.

Hardware (10): The physical machinery of a computer system. It includes components such as printer, disk drive, display screen, keyboard, memory, and central processing unit. See **computer system.**

Heuristic: A rule of thumb for solving a specified type of problem. A step-by-step set of directions that is not guaranteed to work but which seems applicable and has been designed to have a reasonable chance of working. You can think of a heuristic as an **algorithm** that is not guaranteed to work.

Higher-level programming language (10): A programming language, such as BASIC, COBOL, or Logo, in which each statement gets translated by the computer into a number of machine-language statements. See **machine language.**

Higher-order thinking skills (1): The human brain can deal both with simple facts and with complex ideas and relationships. Higher-order thinking skills deal with complex ideas and relationships. For example, why do we say that Columbus discovered America when there were already people living there when he arrived? What makes a president or a prime minister a good leader? Why do some people live in poverty and what can we do about it?

Human-machine interface (9): The hardware and software system that people use to communicate with a computer and that a computer uses to communicate with a person. When this system is designed so that it is easy to use, it is called **user friendly**.

Hypertext (9): A computer-based "text" that may include writing, pictures and drawings, and sound. It may include still and motion pictures that are stored on a videotape or videodisc system. Generally the text is not organized in a linear fashion like in a book. In many cases, hypertext can only be conveniently stored and read by making use of a computer.

Information Age (1): A society in which more people work in information-related and service jobs than work in industrial manufacturing or agricultural types of jobs. In the United States, the Information Age began in 1956. At that time the number of people working in service jobs and information-processing jobs first exceeded the number working in industrial manufacturing jobs.

Integrated circuit (10): A thumbnail-sized circuit containing a large number of transistors and other electronic components. It is often called a chip because of the small piece (chip) of silicone used in its manufacture.

Learning theory (7): A theory about how the brain works when it is learning new things. There are many different learning theories.

Long-term memory: The permanent, or very long-term, storage part of your brain. Your brain has a very large long-term memory storage capability.

Lower-order thinking skills (1): The human brain can deal both with simple facts and with complex ideas and relationships. Lower-order thinking skills deal with knowing simple facts that can be memorized and recalled. For example, what is the name of the small four-footed furry animal that says meow? What does a refrigerator do? What is the Information Age? See also **higher-order thinking skills**.

Machine language (10): Each computer is designed to "understand"—that is, be able to carry out—a limited number of different types of operations. These operations, or primitives, are called the machine's language. Different brands or models of computers may have different machine languages.

Mathematical model (8): The representation of a problem using the vocabulary and notation of mathematics. A formula such as $A = L \times W$ is a mathematical model. This particular model represents the area of a rectangular object in terms of the length and width of the object.

Mental model (8): A model formed in one's head. The representation of a problem via mental imagery.

Metacognition (2): Thinking about thinking.

Model; modeling (8): A model is an abstract representation of something. It represents certain key characteristics well enough so that information gleaned from working with the model is likely to be applicable to the real thing. See also **computer model**, **mental model**, **symbolic model**, and **verbal model**. Modeling is a very important part of solving problems.

Near transfer situation (7): When two problem situations seem quite alike to you. Then you can easily and readily transfer knowledge of how to deal with one of the problem situations to dealing with the other problem situation. A situation that seems to be a near transfer for one person may not be a near transfer for another person.

Network (9): See **computer network**.

Ownership (3): One of the four components of a problem. A problem can only exist if a person or group of people are interested in it, involved with it, and willing to devote time and energy to moving the given initial situation into the goal situation.

Parallel processing: A computer-processing technique that allows the computer to perform multiple processes at the same time, that is, "in parallel." The human brain naturally functions in this manner, since every neuron has both storage and processing capabilities, and many neurons may be working on a problem at the same time.

Pixel (10): Picture element. Think of a computer display screen as being divided into a large number of small dots or elements. A computer can store a picture by storing information about the color of each each element (each pixel) that makes up the picture.

Poorly defined problem (3): A problem situation in which one or more of the defining components—givens, goal, and resources and restrictions—are not clearly defined.

Primitive (5): A problem that you can solve easily, quickly, and accurately. A "building-block" problem is one you can use in the process of solving more complex problems. See also **top-down strategy** and **bottom-up strategy**.

Problem (3): A problem consists of four components: given initial situation, goal, resources and restrictions, and ownership. Many people who define the term "problem" also require that the person who has the

problem not be aware of any immediate and obvious procedure for solving it. Unfortunately, this approach leads to the situation where if one studies and works on a problem sufficiently, it may no longer be a problem.

Problem posing (3): The process of creating a clearly defined problem from a **problem situation**. A person may be able to pose a number of different clearly defined problems from one problem situation.

Problem situation (3): A situation that concerns or disturbs you, a dissonance. A situation in which you are aware of a difference between the way things are and the way you would like them to be. A problem-like situation lacking one or more of the four components of a clearly defined problem.

Procedural thinking: The type of thinking used to develop and/or make use of procedures in solving a problem.

Procedure: A detailed, step-by-step set of directions that can be carried out by a computer. (Or it can be a set of directions that can be carried out in a nonthinking manner by some other machine or person.) Note that a procedure need not have been proven to work or to always work; a "buggy" program is still a procedure. See also **algorithm** and **heuristic**.

Program: In refernce to computers, the word "program" is usually taken as short for computer program or to indicate the process of writing a computer program. See **software**.

Resources and restrictions (3): One of the four defining components of a problem. The types of allowable activities a person is allowed to use in moving from the givens toward the goal in working to solve a problem.

Scale model (8): A physical model of an object, constructed to a scale; for example, one inch in the model corresponds to one foot in the object. Architects often use scale models in designing buildings.

Short-term memory: The temporary storage or active memory part of a brain. The "conscious" short-term memory of most people can store only a few chunks of information.

Smart person (2): You are a smart person if you can understand and can solve a number of the problems you encounter. The more of these problems you can solve, the smarter you are.

Software (10): A detailed, step-by-step set of directions that can be stored in a computer's memory and that a computer can automatically follow. Applications software consists of programs such as a word processor or a database that are designed to help solve specific categories of problems. Systems software includes general purpose programming languages such as BASIC, Logo, and Pascal.

Spreadsheet (9): A computer program that models and helps automate many of the key features of an accounting worksheet.

Strategy (1): An overall or general plan of action for attempting to accomplish some type of task or solve some type of problem. There is no guarantee that the plan will work. There are lots of different strategies that can be used in trying to solve a problem. A common one is to break the problem into smaller, more manageable pieces. See **top-down strategy**.

Symbolic model (8): A model using symbols, such as letters, digits, and diagrams. See **computer model** and **written model.**

Think (6): To use your brain to attempt to understand, pose, or to solve a problem.

Top-down strategy (5): A strategy of breaking a problem into smaller problems. The goal is to arrive at primitives. When all of the primitives are solved and the results are combined in an appropriate manner, the original problem is solved.

Unsolvable problem (4): A clearly defined problem that cannot be solved. For example, "Find two positive even integers whose sum is a positive odd integer."

User friendly (9): The description of a human-machine interface that is easy to use and easy to learn how to use. More generally, a computer system is said to be user friendly if it is easy to use, forgiving of minor errors, and easy to learn how to use.

Verbal model (8): A model formed from spoken words and other sounds. Often the term "verbal model" is intended to include body language. See **verbal/body-language model**.

Verbal/body-language model (8): A model represented by spoken sounds and body language. See **verbal model.**

Word processor (9): A computer program designed to assist in writing. It can be thought of as an electronic typewriter with memory and some other computer-like features.

Written model (8): A model formed by using written letters, digits, punctuation marks, diagrams, pictures, and other written symbols.

Written symbolic model (8): See **written model.**

All you need is the right tool...

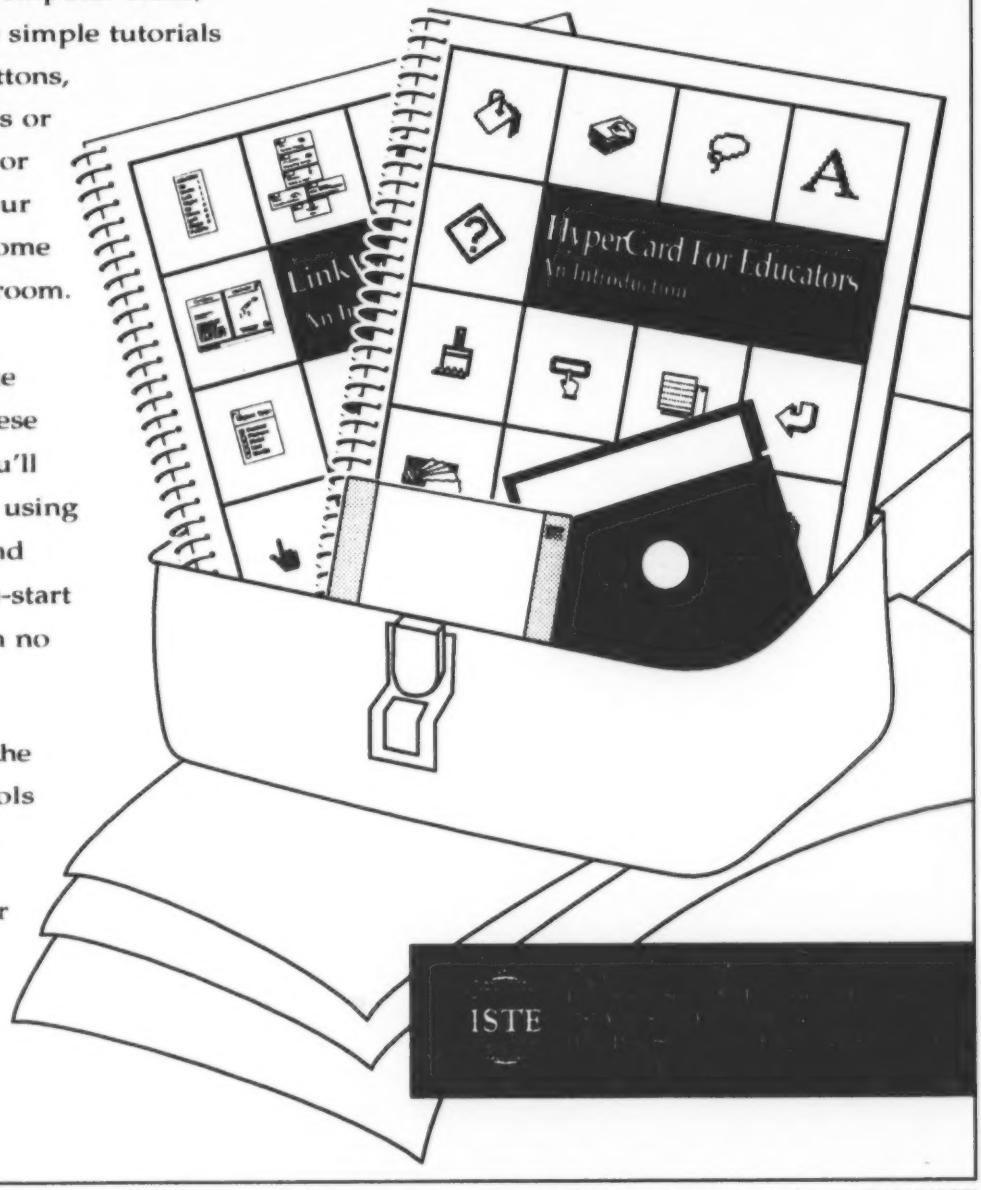
With either *HyperCard for Educators* or *LinkWay for Educators* as an introduction to the interactive world of hypermedia, you can learn to build libraries of knowledge suitable for both classroom and personal use.

If you have basic computer skills, you can follow the simple tutorials and start using buttons, fields, backgrounds or base pages, stacks or folders to make your data and images come alive in your classroom.

By starting with the foundation that these books provide, you'll be on your way to using sounds, images, and animation to jump-start your curriculum in no time!

Take advantage of the organizational tools computers provide.

Call ISTE to order and begin building your *HyperCard* or *LinkWay* skills today.



BEST COPY AVAILABLE

Circle # 20502

Put the Future of Education in Your Hands...

Edutrends 2010
Restructuring, Technology, and the Future of Education
Education, Technology, and Paradigms of Change for the 21st Century
David D. Thornburg, Ph.D.

Pick up David Thornburg's latest in visionary theory and explore the social and technological trends shaping education.

Edutrends 2010—Restructuring, Technology, and the Future of Education

Thornburg examines the recent flurry of teacher bashing, moving from the reasoning flaws of those who would dismantle U.S. public education to the change process necessary for educational restructuring for the 21st century.

He proposes a way to think intelligently about the future while we reshape education to meet the needs of our society.

Education, Technology, and Paradigms of Change for the 21st Century

Learn unique patterns of thinking that encourage students to go above and beyond the three Rs. The technologies of calculators, computers, laser discs, and video games converge with new concepts of learning and intelligence to provide unprecedented opportunities for all students. Let this progressive book lead you toward a future filled with new paradigms.

International Society for Technology in Education
1787 Agate Street, Eugene, OR 97403-1923
Order Desk: 800/336-5191 Fax: 503/346-5890

ISTE Books & Courseware Order Form

Name _____

School/Business _____

Address _____

City _____ State _____ Zip/Postal Code _____

Country _____ Phone _____

☐ Yes! I'm presently an ISTE member. Membership number must be included to receive discount. My membership number is _____ (Discount does not apply to initial membership fee.)

Occupation

Grade Level: ☐ all (K-12) Specific grade level _____

- ☐ Teacher (350) Subject _____
- ☐ Administrator (320) Title/Position _____
- ☐ Higher Education (360) Title/Position _____
- ☐ Federal/State Government (310) Title/Position _____
- ☐ Educational Information Resource Manager (IRM) (320)
- ☐ Technology Coordinator (340)
- ☐ Other _____

Terms & Conditions

Terms: Net 60 orders must be accompanied by authorized company purchase orders. Orders for individuals must be pre-paid, C.O.D., or charged to a Visa, MasterCard, or Discover card number. All non-U.S. orders must be pre-paid.
Shipping: Shipping method is UPS. Add 5% in addition to shipping rate for first class delivery. ***Allow three weeks for delivery.*** Call for rush orders.
Prices: Subject to change without notice.
Returns: ISTE allows return of merchandise, provided the materials are in resellable condition. There will be a 10% restocking charge. All returns must be accompanied by an ISTE Return Authorization form. If you wish to return merchandise, please contact the Distribution Dept. *GST Registration #128828431*

Shipping & Handling for Books & Courseware

$0-$15.99 (subtotal)	add $3.25
$16-$45.99 (subtotal)	$4.50
$46-$75.99 (subtotal)	$5.50
$76-$100.99 (subtotal)	$6.50
$101 or more	7% of subtotal

Do not include *additional site license fees or subscription costs* when computing shipping rates.

Non-U.S. orders for Books & Courseware are sent surface mail. If you want your Books & Courseware order shipped **AIR-MAIL**, please check here ☐ ISTE will bill you the additional shipping charge.

Payment Options

☐ **Payment enclosed.** (Make checks out to ISTE.) Non-U.S. orders must be pre-paid with U.S. funds or credit card.
☐ VISA ☐ MasterCard ☐ Discover Card Exp. Date _____

☐ **Purchase Order enclosed.** (Please add $2.50 for order processing. P.O. not including $2.50 fee will be returned.)

☐ **C.O.D.** for U.S. Book orders only. You will pay UPS the total upon delivery (check or cash—ISTE will add $2.75 order processing).

GST Registration Number 128828431

ISTE Books, Courseware, & Nonmember Subscriptions

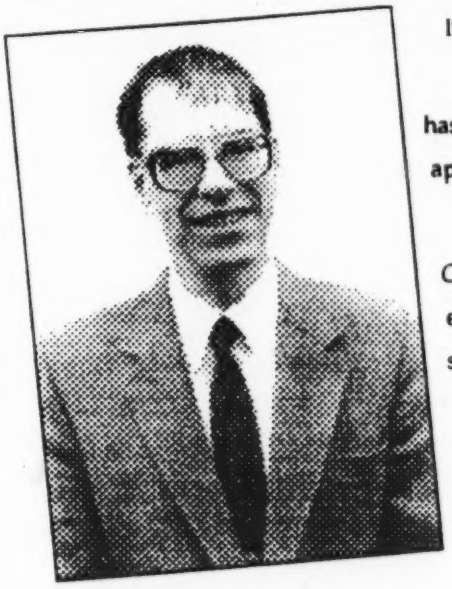
Qnty.	Title	Member Unit Price	Nonmember Unit Price	Total Price

BOOKS & COURSEWARE SUBTOTAL	
Add Shipping, based on Books & Courseware SUBTOTAL	+
Add $10 S & H for Don't Copy that Floppy	+
Add Additional 5% of SUBTOTAL if shipped to PO Box, AK, HI, or outside U.S.	+
Add 7% of SUBTOTAL for GST if shipped to Canada	+
If billed with purchase order, add $2.50. If COD, add $2.75	+
	=
Membership Total from other side	+
TOTAL	=

MAIL this form to:
ISTE, 1787 Agate St., Eugene, OR 97403-1923 USA
FAX this form with credit card or P.O. information to: 503/346-5890
PHONE your credit card or P.O. order to:
ISTE Order Desk: 800/336-5191

BEST COPY AVAILABLE

Dave Moursund knows...



ISTE Executive Officer Dave Moursund is dedicated to improving education.

Since he first began working with computers in education in 1963, Dave has constantly sought to improve education at all levels through the use of appropriate computer-related technology.

As a continuing part of this effort, Dave's newest book—*The Technology Coordinator*—discusses the goals of education and how teachers and teachers of teachers can join in the enormous change process facing today's schools.

This book was written for educators who want to play a leadership role in the instructional use of technology. Dave uses interviews with technology coordinators to illustrate the needs, roles, and qualifications needed to accomplish the goals of educational technology.

In recent years, Dave has focused much of his writing efforts on problem solving and on staff development. Some of Dave's other books also available from ISTE include *Problem-Solving Models for Computer Literacy, LogoWriter for Educators: A Problem Solving Approach, Logo PLUS for Educators: A Problem Solving Approach* (co-authored with Sharon Yoder), and *Effective Inservice for Integrating Computer-as-Tool into the Curriculum.*

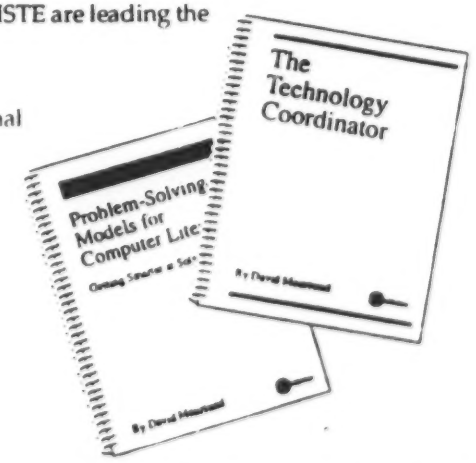
"Our educational system is not nearly as good as it could be," says Dave. "We know that computer-related technology can make substantial contributions to improving both the content of the curriculum and the instructional delivery system. Such technology can empower students and teachers."

ISTE believes that computer-related technology must become a tool that students and teachers use routinely if students are to be adequately prepared for adult citizenship in our Information Age society.

ISTE's wide range of periodicals, publications, projects, and other activities mirror this vision and commitment.

Call us today to order Dave's latest books, and discover how he and ISTE are leading the way for the educators and school systems of tomorrow.

ISTE. Proudly putting you in touch with the world of educational technology.



International Society for Technology in Education
1787 Agate Street, Eugene, OR 97403-1923
Order Desk: 800/336-5191 Fax: 503/346-5890

BEST COPY AVAILABLE

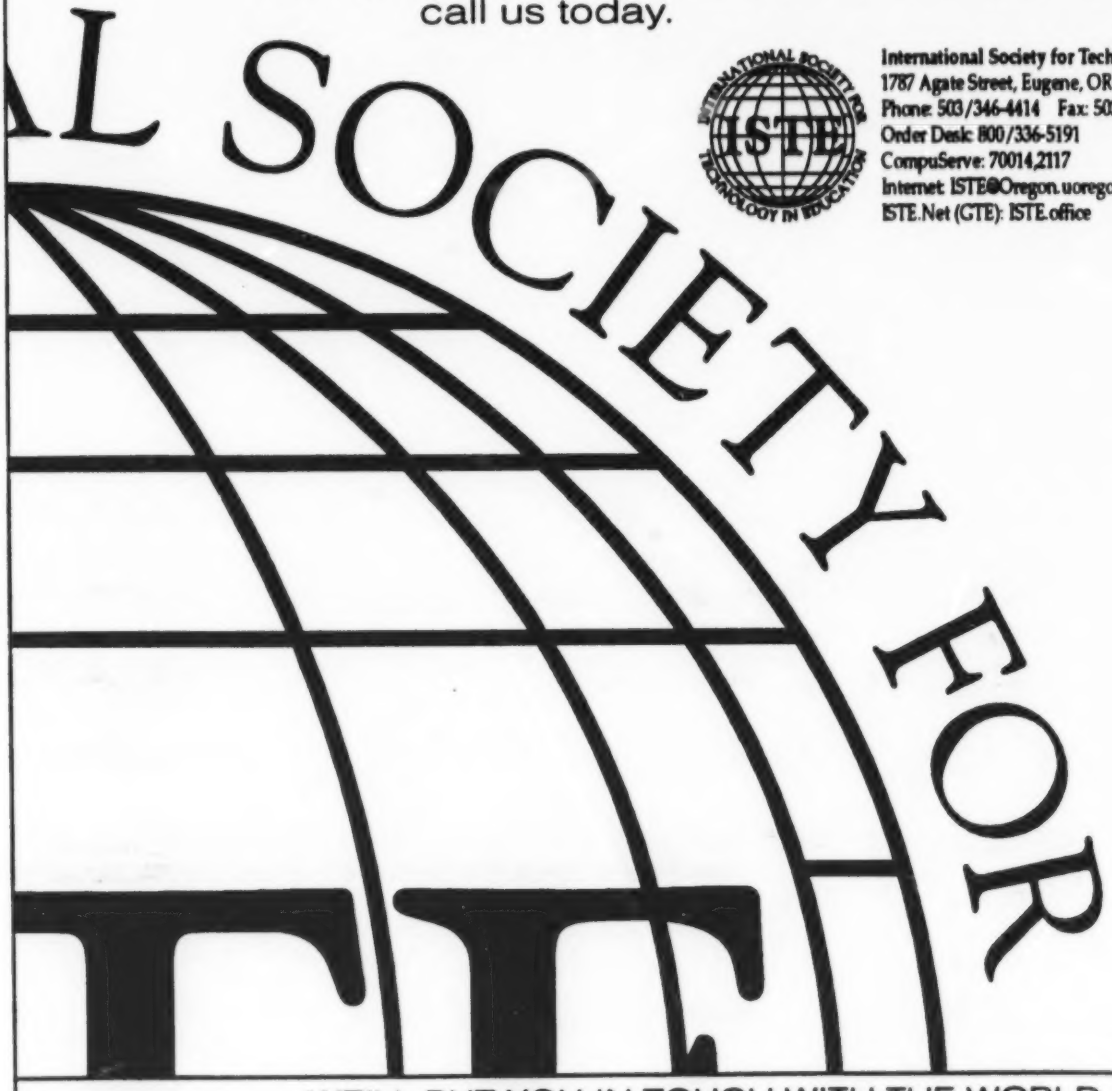
ISTE BRINGS THE WORLD OF TECHNOLOGY CLOSER TO YOU.

By drawing from the resources of committed professionals worldwide, ISTE provides support that helps educators like yourself prepare for the future of education.

ISTE members benefit from the wide variety of publications, specialized courseware, and professional organizations available to them.

They also can enjoy exciting conferences, global peer networking, and mind-expanding independent study courses.

So if you're interested in the education of tomorrow, call us today.



International Society for Technology in Education
1787 Agate Street, Eugene, OR 97403-1923
Phone: 503/346-4414 Fax: 503/346-5890
Order Desk: 800/336-5191
CompuServe: 70014,2117
Internet: ISTE@Oregon.uoregon.edu
ISTE.Net (GTE): ISTE.office

WE'LL PUT YOU IN TOUCH WITH THE WORLD.

BEST COPY AVAILABLE